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A

GENERAL SYSTEM

OF

CHEMICAL KNOWLEDGE.

&c. &c.

A

GENERAL SYSTEM

OF

CHEMICAL KNOWLEDGE;

AND ITS

APPLICATION

TO THE

PHENOMENA OF NATURE AND ART.

BY A. F. FOURCROY,

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IN ELEVEN VOLUMES.

TOGETHER WITH A SET OF SYNOPTIC TABLES, IN LARGE FOLIO.

TRANSLATED FROM THE ORIGINAL FRENCH,

BY WILLIAM NICHOLSON.

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A SYSTEM OF CHEMICAL KNOWLEDGE.

CONTINUATION OF THE

SEVENTH SECTION.

Article IV.

Concerning the Eleventh of the immediate Materials of Vegetables.

Of Camphor.

A. *Situation.*

1. CAMPHOR was not formerly confidered as one of the immediate materials of vegetables, but merely as a principle peculiar to that tree of Molucca which affords it. Slare and Ludovic firft obferved it in old oil of Canella; Kunckel in the thick oil of annifeed and rofemary; Cruger in oil of marjoram kept twenty-feven years. Geoffroy has extended and confirmed thefe obfervations by afcertaining the exiftence of camphor in many effential oils, and obferved that it falls down in the courfe of time from them,

particularly from the oils here mentioned. After these chemists, Cartheuser discovered it in a great number of plants. Prouſt has accurately described the art of extracting it, even with profit, from various species of volatile oils, which grow abundantly in the province of Murcia.

2. The tree which affords camphor is a species of laurel, which grows abundantly at Ceylon, at Borneo, and in the island of Java. It also exists in the roots of canella, zedoary, sassafras, in the oils of thyme, rosemary, sage, lavender, marjoram, and matricary. Citizen Josse, apothecary at Paris, has obtained it in sufficient quantity to ascertain its nature from the roots of elicampane: I have found very evident traces of it in the roots of Valerian. It exists in general in various volatile oils, which hold it in solution, and suffer it to precipitate, either by spontaneous evaporation or by the action of fire. Many chemists affirm, that thyme and pepper-mint, slowly dried, afford much camphor by distillation. Mr. Achard has observed, that a smell of camphor is disengaged when the volatile oil of fennel is treated with nitric acid; that the oil of anniseed afforded it in crystals by the same acid; and lastly that vinegar, charged with oil of angelica, let fall camphor by the addition of pot-ash.

3. All these facts united, leave no doubt respecting the existence of camphor in a great number of vegetables. There is reason to think

that

that it will be ſtill more abundantly found when experiments ſhall be multiplied on this head. We muſt not therefore any longer conſider camphor as a principle peculiar to any ſingle vegetable, but truly as one of the immediate materials of plants among which it ought to be arranged.

B. *Extraction.*

4. NOTWITHSTANDING the exiſtence of camphor, as it appears in many vegetables, that which is moſt abundantly employed, becauſe moſt eaſily extracted, is obtained in the Moluccas from the laurus-camphora of Linnæus, or the camphorated laurel. This tree grows ſpeedily, and in great numbers, in the iſlands of Sumatra, Borneo, Java, and in Japan. Many travellers aſſert, that this tree contains it ſometimes in ſo great quantity, that nothing more is neceſſary than to ſplit it, in order to obtain conſiderable maſſes in a pure ſtate. It is obtained from this vegetable by diſtillation. The roots and branches of the camphor-bearing laurel are put into a great alembic with water. A head is adapted, the inner part of which is fitted up with ſtrings made of rice-ſtraw. The heat which is applied volatilizes and ſublimes the camphor, which adheres to the cords in the form of ſmall greyiſh, dirty grains, which are united by rubbing into larger pieces. The

camphor thus collected is impure. It is refined in Holland by fublimation, in which one-fixth of its weight of chalk is ufed. Some perfons affure us that this operation is made without any addition in galleries placed over long furnaces conftructed on a flope, in which the fire is kept up by letting fall fucceffively in the direction of thofe fires the membranous envelops or chaff of buck-wheat, *polygonum fagopyrum*. Thefe envelops of the farrazin are feparated by fwelling with water, and the fubfequent effect of a gentle heat. They take fire with rapidity on account of their drynefs.

5. To thefe accounts of the ancient art of extracting camphor from the laurel, it is neceffary to add in this place a fhort notice of operations refpecting the extraction of camphor from various volatile oils, being part of a differtation of Mr. Prouft, a French chemift, Profeffor at Segovia fince 1784, publifhed in Spanifh in that town in 1789, under the following title: *Refultado de las experiencias hechas fobra el alcanfor de Murcia. Conlicencia en Sigovia pordon Antonio Efpinofa.* I fhall follow a very ample extract inferted by Mr. Arezula, a Spanifh chemift, one of my pupils, in the Annals of Chemiftry, vol. iv. p. 179. Mr. Prouft having obferved, in a bottle of volatile oil of lavender, different ramified cryftals formed of octahedrons, placed upon each other, and a kind of fnow depofited on that part of the bottle where the oil had been fpilled on the outfide, thus

difcovered

discovered the presence of camphor in the oil, and suspected that it existed also in those of various other labiated plants of Murcia, a province very fertile in this genus of plants, and which afford much of the volatile oils of commerce. A continuation of his inquiries soon showed, that evaporation in the open air is a very proper means to separate the camphor from these oils. At a temperature between 6 below 0, and 10 above 0 of the thermometer of Reaumur; he exposed it to the air in plates of porcelain, in a still place, considerable quantities of oil of rosemary, of marjoram, of sage, and of lavender from the country here mentioned. Spontaneous evaporation was sufficient to afford him camphor in crystals, one-sixteenth of the weight of that of rosemary, near one-tenth of that of marjoram, nearly an eighth of that of sage, and upwards one-fourth of that of lavender. He did not, however, keep any account of that which was dissipated with the oil volatilized in the air: so that those quantities, though considerable, are still less than was contained in the oils themselves. The oil of lavender, the most rich in camphor, afforded a first portion of this body separated after twenty-four hours; it had the form of blades intertwined together, and he separated the portion of oil which adhered by mere suspension in a funnel. At fifteen degrees the speedier evaporation caused the camphor of this volatile oil to separate after twelve hours exposure to the air. In very hot seasons, the distilled oil carries so much with it that it deposits it in cooling; and an apothecary of Madrid assured Mr. Arezula, that by this simple process camphor had long been obtained from the volatile oils of Murcia, and was sold for thirty sous the *(quantity not mentioned in the original)* in commerce. The volatile oil of sage deposits its camphor rather more slowly than that of lavender, and it is more difficult to separate the portion of oil which hangs about it. The camphor thus obtained and dried on blotting paper was dry, white, and brilliant, like snow; it scarcely exhibited the odour of the oil from which it was afforded.

By distilling the oils of lavender on a water-bath of considerable extent, but shallow, placed at some distance from water kept at the heat of several degrees below the boiling point, until a third of these fluids is drawn over, and the apparatus being then left to cool, two-thirds of that which remains in the vessels are obtained, consisting of camphor crystallized and precipitated, which may be taken out with a skimmer, then drained in a sieve, or slightly compressed. The remaining oil is to be treated with other water as before. The heat of the ebullition and the distillation, urged still farther, cause the camphor to rise by sublimation in the head. When the operation is thus finished, one half of the camphor contained in the oil will have been obtained. Three successive operations are sufficient to deprive oil of lavender of the camphor it is capable of affording. It is not possible to obtain by this means more than a fifth, instead of the fourth part which it really contains.

The

The residue contains a seventy-second part, and the distilled oil six of the same parts. Mr. Proust estimates, that in the large way this oil will not afford more than fifteen parts out of seventy-two of camphor, instead of eighteen, which it in fact contains.

By refining the camphor thus obtained by sublimation, the professor of Segovia made several important observations. Twenty-four parts of this product afforded him only twenty-two of very white solid and pure camphor. The two twenty-fourth parts which remained were too strongly heated, which rendered them of a brown-red, owing to a resinous substance, which, having been taken up with the alcohol, was precipitated by water of a tenacious and reddish appearance, whereas the camphor itself was precipitated in white flakes. This resin arising from a small quantity of oil remaining between the crystals of the camphor in the first operation, prevented the sublimation of the last portion, Lime facilitated its purification, and afforded twenty-three twenty-fourth parts of white dry camphor. Washed ashes succeed equally well. White clay afforded yellow camphor. He advises the use of lime or washed wood-ashes in preference to the clay, which he rejects. It is necessary that these substances should be very dry, because the water they contain produces a boiling in the mixture, the projected fluid from which would soil the sublimed camphor. Fire of considerable strength, and shallow vessels, contribute much to afford the camphor in white solid

ſolid loaves, as it ought to be for the market. The fuſed camphor may be boiled before the ſublimation, becauſe it is leſs volatile than the oil, and a ſtronger heat is required to raiſe it than would be ſuppoſed, from the ancient notions reſpecting the volatility of camphor. This is the only means of obtaining it tranſparent and in maſſes; and it appears that this is the ſecret of the Dutch refineries. The ſublimed camphor contracts in cooling, and breaks in various places; it ſeparates very well from the veſſel; whereas, when leſs heated, it is lamellated, rous or ſpongy, and adheres much.

The author, from the ſimple and preciſe calculations founded on the price of oil of lavender, the camphor of Murcia, and the charges of the operation which he deſcribes for extracting and refining camphor, compared with the product he obtained, concludes that the advantage would be from ſixty to ſixty-three per cent.

Oil of ſage treated in the ſame manner as that of lavender, though it requires but one third of the product to be volatilized, does not afford, according to him, more than a profit of twelve or thirteen per cent. on account of the leſs quantity of camphor it contains; the oil of marjoram affords between ten and eleven per cent and that of roſemary ſtill leſs, as it does not exceed four or five per cent.

Mr. Prouſt concludes this intereſting reſearch with a compariſon of the properties of the

camphor

camphor extracted from the oil of lavender of Murcia with thofe of the camphor of commerce, and he found the effects of the nitric acid upon the one and the other to be abfolutely the fame. Each furnifhed, after having precipitated them from the nitric acid by means of water, a lofs of thirty-five per cent. concerning which I fhall fpeak hereafter.

6. Thefe interefting details afford reafon to prefume that much advantage might be derived from the labiated plants which grow fo abundantly in the fouthern departments of the French Republic, and particularly from the greater lavender, *lavendula fpica*, the fame as that of Murcia from which the oil of afpic is extracted. Though the difference of climates might produce fome modification in the quantity of the product, there is reafon to hope that this oil, fo abundant and fo cheap in comparifon with the other volatile oils, would afford camphor by the proceffes of Mr. Prouft, and thus fupply us with a new article of trade, for which the nation would no longer be under the neceffity of paying to foreigners in ready money.

C. *Phyfical Properties.*

7. Very pure camphor is a white, concrete, tranfparent body, cryftallized in octahedrons or fquare plates, of which the fpecific gravity is in comparifon to water, upon which it floats, as 9,887 to 10,000. Its tafte is acrid, hot, penetrating,

netrating, and bitter. Its ſtrong and diſagreeable ſmell gave riſe to the adage of Salerneum, *Camphora per nares caſtrat odore mares*, becauſe it has long been ſuppoſed to poſſeſs a calming and ſedative property; but it is very far from poſſeſſing that property to the extent denoted in that verſe.

8. When it is placed in fragments, even of conſiderable magnitude upon water, the fluid moves round the fragments, and circulates as if it gradually attacked their ſurface. Small cylinders of camphor, placed vertically in water ſo as to ſtand above its ſurface, but alſo fixed in ſuch a manner as to remain in part beneath, are cut in two, according to the obſervation of Venturi, Profeſſor of Natural Philoſophy at Modena, at the preciſe level of the water. Very ſmall pieces of camphor thrown upon water are agitated, and moved about with great rapidity. A drop of oil let fall upon the ſurface of the liquid immediately ſtops the motion, which was erroneouſly attributed to electricity, but appears to be owing to the attraction of the particles of camphor, water, and air, and to be a true combination between theſe three bodies.

9. Camphor is one of the moſt volatile ſubſtances we know; it appears nevertheleſs, from the experiments of Prouſt, to be leſs ſo than volatile oil. But we muſt not overlook that this is to be underſtood reſpecting its combination with the oils, and not with regard to pure and inſulated camphor. Camphor in a cloſed

veſſel,

veſſel, expoſed to a temperature ſuperior to ſixteen degrees of Reaumur's thermometer, continually riſes in vapour, and is inceſſantly ſublimed. The upper part of the ſides of the veſſel is found to be covered with cryſtalline grains of camphor variouſly grouped upon the ſurface of the glaſs. It appears in this caſe, that the heated air diſſolves it, and afterwards, by cooling, depoſits it on the ſides of the veſſel.

10. Camphor is alſo fuſible at a temperature, which Citizen Venturi eſtimates at 120 degrees of the thermometer of Reaumur. Mr. Prouſt deſcribes it in a ſtate of fuſion and ebullition before it riſes in vapour. In fact we may ſuppoſe that the twenty-fourth part of volatile oil, to which it was ſtill united, had an influence on its fuſion, notwithſtanding its ſmall quantity. In this ſublimation, the camphor cryſtallizes in a different manner from that which it exhibits when it abandons its oily ſolvent, and a few traces of octahedrons are perceivable only in the caſe of its volatilization in ſmall irregular grains. Citizen Venturi affirms, that it ſublimes at fifty degrees of the thermometer of Reaumur. According to the ſame philoſopher, it evaporates at the ordinary temperature of the atmoſphere in the vacuum of the barometer.

D. *Chemical Properties.*

11. While it prefents fome analogies with the volatile oils, camphor exhibits very remarkable differences. When placed in contact with a burning body, it takes fire brifkly, and emits a very white flame with abundant fumes. Citizen Lagrange burned it in oxigen gas or mercury, in the fame manner, as Lavoifier burned carbon and phofphorus. He obtained much fublimed charcoal, carbonic acid gas, and another acid, of which the nature is not accurately determined, but which he compared to the camphoric acid. By diftilling camphor ground with alumine, in order to fix it in a certain refpect, he extracted a golden-yellow coloured oil, of an acrid tafte, and of a fmell refembling that of thyme and rofemary, volatile in the air, forming a liquid foap with the cauftic alkalis, foluble in alcohol, becoming white in the oxigenated muriatic acid: a very black and very pure coaly matter remained in the alumine. According to the fame chemift, a fmall quantity of camphoric acid is formed during the diftillation of camphor.

12. The union of the fimple combuftible bodies with camphor, particularly phofphorus and fulphur, has not been yet examined. Water diffolves it in a very fmall quantity, which, however, is fufficient to produce a very perceptible acrid fmell and tafte; when camphor is burned upon

upon water, the fluid contracts a very perceptible acid taste, and other properties.

13. One of the great differences between campor and the volatile oils, is the manner in which it is affected by the strong acids. Concentrated sulphuric acid dissolves it, and by the assistance of heat, sulphureous acid and hidrogen gas are disengaged; the fluid becomes of a violet or brown-red; and it is ascertained that carbon is separated, and water with an acid is formed. The nitric acid dissolves it effectually, if it be but little concentrated. This yellowish solution separates into two liquids; that which floats above has been improperly denominated *oil of camphor;* the portion beneath contains camphor already altered and acidified; for when the upper fluid is precipitated by water, which separates camphor in the solid state without alteration, more than a third of this combustible body is found to have disappeared. The gaseous muriatic acid also dissolves camphor, and puts it into the aëriform state; the same is the case with the fluoric acid gas. Water precipitates the camphor of these solutions in the solid state, as it does the nitric solution.

14. Mr. Kosegarten long since discovered that the nitric acid, distilled in a considerable quantity from camphor, converts it into a peculiar acid. Citizen Bouillon has confirmed this discovery, and carried his researches concerning this acid much farther. In order to obtain it, eight parts of nitric acid, at thirty-six degrees, are

are poured upon one part of camphor in a glaſs retort. Heat is given by a ſand-bath, and much nitrous gas with carbonic acid is diſengaged, at the ſame time that a ſmall portion of unaltered camphor ſublimes. This operation is repeated three times upon the ſame camphor. The camphoric acid is cryſtallized by the cooling of the fluid which remains in the retort. It is purified by ſolution in boiling water and cooling. The acid thus obtained does not amount to quite half the weight of the camphor. This acid, which appears to cryſtallize in acute octahedrons, has a ſlightly ſour but conſiderably bitter taſte. It reddens turnſol, and effloreſces in the air. Cold water diſſolves ſcarcely more than one-three hundredth of its weight; boiling water, on the contrary, diſſolves nearly one-twelfth. Upon ignited charcoal it emits an acrid aromatic denſe fume, and is entirely diſſipated. It melts and ſublimes by a regulated heat. When paſſed through an ignited tube with oxigen gas, it remains without alteration. Neverthelefs, by diſtillation in a retort, Citizen Lagrange had expectation of decompoſing it, as it loſt its acid nature, its ſolubility in water, and had acquired an aromatic odour. This acid is alſo ſoluble in oils. Its combinations with the earths, the alkalis, and the metals, are different from thoſe of all the known acids. It does not precipitate lime-water; the camphorate of pot-aſh, and ſeveral other camphorates, are very cryſtallizable. The camphoric acid precipitates

pitates various metallic ſolutions, particularly the ſulphate, and the muriate of iron.

15. Camphor is not changed, nor ſoluble in the alkalis. No ſalt acts upon it, except the ſuper-oxigenated muriate of pot-aſh, which burns and deſtroys it by a blow or by preſſure. It has no attraction for the metallic acids, nor for the ſolutions of the metals. It mixes, and is ſuſpended in water by the medium of ſugar, or the mucilages. Fixed and volatile oils diſſolve it, and nature frequently preſents this ſolution, as I have already ſhown.

16. Though the accurate analyſis of camphor and its chemical properties are yet far from being known with the accuracy that may be wiſhed, thoſe which I have here pointed out will ſufficiently diſtinguiſh this body from volatile oils, and to juſtify us in admitting it as one of the immediate materials of vegetables, which deſerves to be carefully ſtudied. Its property of forming a peculiar acid by the action of fire, or of the nitric acid, is ſufficiently characteriſtic. It was lately conſidered as a volatile oil, more carbonated than thoſe which are particularly diſtinguiſhed by that denomination.

E. *Species.*

17. If there be truly no more than one ſpecies of camphor always of the ſame nature, whatever may be the vegetable from which it was obtained,

obtained, it is neverthelefs true, that, together with the refemblance of the greateft number of its diftinctive properties in the different plants which contain it, it alfo prefents certain differences, particularly that of an odour refembling the vegetable form from which it was extracted. Under this point of view, we may therefore admit as many fpecies as there are plants hitherto difcovered which afford it, though the qualification of fpecies may be really too marked a term to diftinguifh fimple varieties. Thus, befides the true camphor obtained from the camphor-bearing laurel, we may admit the camphor of lavender, of fage, of rofemary, of marjoram, of anifeed, of faffafras, &c. This diftinction, however, muft become either more accurate or ufelefs at the period when chemifts, after comparing thefe different varieties of camphor, fhall have difcovered characters peculiar to each, or have confirmed their perfect identity.

F. *Ufes.*

18. CAMPHOR is one of the moft powerful remedies which medicine poffeffes. As a topical remedy it calms inflammations, ftops gangrene, and diffolves various tumours. Internally, it is anti-fpafmodic and antifeptic. It is very fuccefsfully employed in contagious diforders, in intermittent or putrid fevers, as well as thofe of a malignant and nervous defcription. It is particularly active in affections of the urinary paf-

fages,

ſages, and ſtops the pernicious effects of cantharides on thoſe organs. It is preſcribed in the doſe of ſeveral grains in pills, boluſſes, electuaries, mixtures, in which it is diffuſed by means of the yolk of egg, mucilages, and ſugar. Its ſolution in alcohol is much employed internally. It enters into a great number of pharmaceutic preparations.

19. It is particularly uſed in embalming. It powerfully preſerves putreſcent ſubſtances, ſtops the ſeptic alteration, as is proved by all the experiments of the moderns upon putrefaction and antiſeptics. It is much employed to defend furs, feathers, and animal ſubſtances in general, particularly preparations of natural hiſtory from alteration. It operates in this reſpect, by preventing the approach of inſects, and accordingly it is much uſed in cabinets and collections of animal matters from America and India.

20. Camphor is alſo of uſe in ſome of the arts as a combuſtible ſubſtance. It is an ingredient in fire-works, and is ſaid to have been a part in the famous compoſition named the *Greek fire.* Moſt of the incendiary preparations, intended to produce their effect in water, likewiſe contain a more or leſs conſiderable quantity.

Article XV.

Concerning the Twelfth of the immediate Materials of Vegetables, namely, the Resins.

A. *Situation.*

1. UNDER the article of volatile oils we have seen, that when exposed to the air, they become condensed and converted into resin. It seems, therefore, that there is no other difference between these substances but the condensation here mentioned, and that we may define resins by the name of condensed volatile oils. But this simple exposition gives us but a very imperfect notion of resinification, that is to say, the conversion of those oils into resin. It is very evident, in fact, that the resins owe their origin entirely to the volatile oils, that they are always first in this state; but in this simple expression of the fact, we do not see the manner of operation or the cause which produces the effect, or the true result it affords. It is necessary to examine the phenomenon more narrowly, in order to ascertain what resinification consists in, and to determine what happens during the conversion of the volatile oils into resin.

2. Mr. Proust, in his Dissertation on Camphor, observes, that most of the volatile oils when exposed

pofed to the air, are feparated into two fubftances, one of which is acid, and the other refinous. It is probable that the former is analogous to the Benzoic or camphoric acid. With regard to the converfion of a portion of volatile oil into refin, this chemift attributes it to the abforption of oxigen, as well as acidification; and he explains thefe fimultaneous changes by admitting two different fubftances in the oils, one a fpecies of acidifiable radical, and the other refinifiable radical. Though this ingenious theory may appear to fatisfy the phenomena, or rather the refults obtained by the expofure of the volatile oils to the air, it is far from being yet confirmed by experience.

3. Experience indeed proves, that by expofing the volatile oils to the contact of oxigen gas, as well as by treating them with bodies which can eafily communicate this principle, they in fact become condenfed, and approach to the nature of refins, at the fame time that they are partly acidified; but it does not exactly prove that thefe changes are owing merely to abforption of oxigen. On the contrary, we find by expofure of thefe oils to the air, that they are more difpofed, as I have obferved, to lofe or part with a portion of their hidrogen, than in truth to abforb oxigen. They gradually form water, which is collected even on their furface, or which lines the infide of the glafs veffels in which this experiment is made with very vifible drops; and as thefe oils become at

 the

the ſame time more denſe, we may attribute their reſinification much more to the loſs of their hidrogen, than to the abſorption of oxigen. They alſo at the ſame time ſuffer a portion of their carbon to exhale; for the air in which they have remained for a long time becomes charged with a greater or leſs quantity of carbonic acid.

4. We may in the mean time, and this is the moſt juſtifiable conduct to be purſued, until inquiries ſhall have been carried further on this object;—we may admit the contemporaneous action of the air upon the volatile oils, the loſs of hidrogen, and its abſorption of oxigen from them, admitting, at the ſame time, that the latter of theſe phenomena is much more evident than the communication of oxigen. We may define reſinification to be a ſpecies of oxidation of volatile oil, owing to the diſſipation of part of their hidrogen, and the abſorption of a ſmall portion of oxigen. Hence we may conceive why few oils paſs to the ſtate of reſin, in what manner reſinous matter is formed in vegetables, why this formation takes place at their ſurface, where the volatile oils flow out, and alſo in their barks or firſt ligneous ſtrata.

5. From this theory, which is defective only in point of preciſion, we may conceive, that reſin is to volatile oil the ſame thing which vegetable butter or wax is to fixed oil. Nothing more will remain but to determine the proportion which exiſts between the ſame volatile oil and camphor;

camphor; whence it happens that certain ſpecies of this genus contain camphor, that others are more diſpoſed to form reſin or benzoic acid, if it be true that each of theſe three bodies, camphor, reſin, and benzoic acid, be not a peculiar modification of volatile oil, and each of them be not capable of paſſing to either of the ſtates reſpectively by a determinate variation of its principles. Whatever may be the caſe, it is eaſy to conceive that reſin will be found in thoſe ſituations where volatile oil is found, and that every thing, which is obſervable with reſpect to the oil, is applicable alſo to reſin as far as relates to its ſituation.

B. *Extraction.*

6. Resin frequently flows from the external parts of vegetables in a ſoft and partly liquid ſtate, as will be ſeen in moſt of the ſpecies of this genus. The efflux is ſometimes accelerated by boring holes, or making inciſions in the trees which are capable of affording it, as is done with regard to all thoſe denominated reſinous, ſuch as the pine, the fir, the larch, &c. It then flows out in the form of a thick, viſcid, tranſparent fluid, often with little ſmell, which is collected in a more or leſs conſiderable quantity.

7. Frequently alſo the reſin remains in the vegetable organs where it was formed; acquires a ſolidity more or leſs conſiderable; becomes dry and

and brittle; is depofited in plates or thin leaves, or varnifh—like ftrata, which cannot be extracted by preffure, or any other mechanical means. Neverthelefs it fometimes happens, that after having obferved in the texture of folid vegetable fubftances, diftinguifhable by its brilliancy, its vitreous texture, and its brittle property, it is found to feparate in the form of a powder more or lefs coloured, becoming fatty and unctuous by preffure and pulverization, and not to be confounded with the woody powder or fibrous lamellated fecula obtained by rafping or pounding folid vegetable fubftances. This fact is obfervable in the operations of pharmacy, and of perfumery; but it is not fufficient for chemifts; and whatever precautions they may take, they cannot by this means procure a quantity of refin fufficiently abundant for their experiments, or fufficiently pure to be ufed in their refearches.

8. When the refin exifts dry in very fmall fragments or thin plates, in dry vegetable matters, as here pointed out, there are two methods of extracting and feparating this refin from other vegetable fubftances with which it is mixed. The one, which is not commonly employed with this view, takes place in the decoctions to which various folid vegetable bodies, fuch as the roots, the wood, the bark, the fruits, &c. are fubjected. The heat of boiling water foftens and melts this refin, which feparates, and is often collected in the form of oily,

yellow,

yellow, red, or brown drops at the furface of the water, which afterwards becomes more denfe and hard, and falls to the bottom of the liquid; but in this cafe it mixes, and is confounded with the extractive matter, which, as we have feen, becomes infoluble and folid by the action of the atmofpheric oxigen. The other procefs, which is the only means practifed in chemiftry to extract the dry refin from vegetable bodies which contain it, confifts in applying an appropriate folvent. Alcohol is employed for this ufe; it is left to macerate for a certain time on vegetable fubftances, from which the refin is to be extracted, and which have been previoufly ftamped, pounded, or cut into fmall pieces: it is fometimes boiled, and afterwards evaporated to drynefs, fo that the refin remains alone and dry; neverthelefs it is mixed with fome other immediate principle of vegetables. It is feparated by precipitation with water.

C. *Phyfical Properties.*

9. Resin is either foft, vifcid, liquid, or dry, brittle, of a glaffy appearance; fine-grained, and more or lefs beautifully tranfparent. Its white, or greenifh yellow colour, when liquid, is extremely varied in the different fpecies when dry and brittle; moft commonly it is of a lemon or amber-yellow colour, of more or lefs bright red, or red-brown. It is found of a red-

red-brown, green, or deep red colour; but in this case it is always opaque. It is easily reducible into powder, and its powder is unctuous, and sticks together by percussion.

10. All the resins are rather heavier than water. Their specific gravity varies from 10,452 to 12,289, water being 10,000. Most of them have no taste, or a very weak taste, even when masticated for some time. Their smell is almost always weak, and does not become perceptible but by long grinding, or an elevated temperature. Resins have almost constantly a decided character of acidity.

11. The resins, exposed to the weak action of caloric, soften and melt like wax without alteration. Each requires a particular temperature for its fusion. By cooling, they resume the concrete state. It is well known that resins insulate and intercept the passage of the electric fluid, and that they are themselves electric by friction.

D. *Chemical Properties.*

12. Resin, treated by fire in close vessels, affords volatile oil in quantity greater as the resin is softer. Thus it is that turpentine, and all the trees of the genus *pinous*, afford very great proportions of volatile or essential oil. The residue is a resinous matter much drier than before, and frequently of a brown or black colour. If the fire be urged still more, the product

is

is water, an acid liquor, carbonated hidrogen gas, carbonic acid gas, and there remains a voluminous charcoal more abundant in its bulk than from the volatile oils.

13. Resin, heated with contact of the air, takes fire after having melted and boiled up; its flame is strong and large, and its smoke considerable; it affords a very abundant soot, which is condensed and collected in some manufactories in cones of plate-iron, under the name of lamp-black. Much water is also formed in this combustion.

14. Resin unites by fusion with sulphur; more difficultly with phosphorus, and not at all with the metals. There is no union between resin and the metallic oxides, in which respect these bodies differ much from fixed oils. There is no action between resin and water. When resin is inflamed, it decomposes water poured upon it, and produces an explosion, which however is less violent than that occasioned by the fixed oils.

15. Neither the acids nor the alkalis exercise any action upon resin, by inflaming, burning, or converting it into soap. This want of effect resembles the property of oily oxides, and favours the opinion of those who think that resin owes its state to the absorption of oxigen. The same is the case with regard to the oxigenated muriatic acid, the oxides, and the metallic solutions.

16. It

16. It is almoſt ſuperfluous to obſerve in this place, that liquid reſins which contain the greateſt quantity of volatile oil, are more alterable in general than the dry and brittle reſins; it may eaſily be conceived that they muſt participate in the characters and properties of the oils they contain.

E. *Species.*

17. The number of the ſpecies of reſin is very conſiderable. There is ſcarce a plant or vegetable which does not contain it, and from which it may not be extracted by ſome chemical proceſs. An enumeration of the ſpecies would therefore be impoſſible, illuſive, or unneceſſary, if we did not confine ourſelves particularly to thoſe which are moſt uſeful, the moſt eaſily extracted, and which nature itſelf offers to man by their ſpontaneous flux, which are the moſt abundant, and at the ſame time moſt frequently employed in the arts. I particularly reckon the thirteen following reſins, obſerving, that ſome of them are known in commerce by the name of balſams, on account of their liquid ſtate only, and not from their nature, becauſe they are not true balſams, as I ſhall ſhow, when I treat thoſe ſubſtances in one of the following articles.

A. Balſam of Mecca, from Judea, Egypt, and Grand Cairo. This is a liquid, white, bit-

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ter refin, of a very ftrong fmell of lemon, which flows from the tree called *amyris opobalfamum*, found by Forfkahls in Arabia Felix, and placed by Linnæus in the clafs of *octandria monogynia*. This liquid refin affords much volatile oil by diftillation; it becomes thick by long contact of the air, and forms a folid cruft at its furface. It is ufed in medicine as a vulnerary, incorporated with fugar, the yolk of egg, &c.

B. Balfam of *Copahu*, another fpecies of brown or yellow liquid refin, which flows from the tree called *Copaiba*, named by Linnæus *Copaifera*, and placed by that botanift in the clafs of decandria monogynia: the common fpecies, as well as that of the balfam of Tolu, a true balfamic juice of which I fhall hereafter fpeak, is a mixture of true refin of copahu and turpentine, according to Cartheufer. It is employed in medicine in ulcers of the lungs, and the bladder, like the preceding.

C. Chio turpentine flows from the turpentine tree, which affords the piftachia nut, terebinthus piftachia of Linnæus; it is of a white or blueifh-yellow colour. It affords a very pure volatile oil on the water-bath. That which it affords to a naked fire is lefs fluid. The turpentine is afterwards yellower; if it be diftilled with water, it becomes white and filky, and is denominated boiled turpentine. This turpentine, the only fpecies which ought to bear the prefent name, is fcarce and little ufed.

D. Venice

D. Venice turpentine, or refin of the larch, is commonly employed in medicine. It is ufed in its natural ftate, or combined with fixed alkali. This combination is the true foap of Starkey, or the faponule of turpentine. In order to prepare it, the Paris difpenfatory prefcribes to pour on two parts of nitre fixed by the tartar and ftill hot, one part of the volatile oil of turpentine; to agitate the mixture with an ivory fpatula, and to cover the veffel with paper; the oil is gradually to be added until the whole forms a white mafs. As this procefs lafts feveral months, chemifts have endeavoured to difcover the means of making the foap in a more expeditious manner. Rouelle, by triturating drop by drop, the alkali with the foap, and adding a fmall quantity of water towards the end prepared in three hours a confiderable quantity of this faponule. Citizen Baumé advifes levigation upon a ftone of one part of alkali of tartar, dried fo as to enter into fufion, and gradually to add two or three times its weight of volatile oil of turpentine. When the mixture has acquired the confiftence of a foft opiate, it is put into a glafs bottle covered with a paper, and expofed in a humid fituation. In fifteen days, the deliquefcent alkali forms a particular ftratum of the fluid at the bottom of the veffel; the foap is in the middle, and a portion of the oil which has acquired a red colour, floats at the top. Citizen Baumé thinks that the

the alkali unites only with that portion of the oil which is in the ſtate of reſin. Legendre extends this notion by propoſing to ſaturate fixed alkali without heat in ſolution with thickened oil of turpentine, or turpentine itſelf.

This ſaponule has a certain degree of ſolidity, which gradually becomes more conſiderable; it forms cryſtals which have been conſidered as a combination of the acid of the oil with the vegetable fixed alkali, which, according to the academicians of Dijon, are only pot-aſh ſaturated with carbonic acid, and cryſtallized. As this ſaponule is very difficult to make, and very changeable, Macquer thinks that when it is deſirable to unite the properties of volatile oil with that of ſoap, it is better to incorporate with the white medicinal ſoap ſome drops of the volatile oil appropriated to the indication intended to be anſwered. Ammonia, triturated with turpentine, forms a ſaponaceous ſolid compound, which is very ſoluble in water, and renders it milky and frothy.

E. The reſin of the fir is named Straſburg turpentine. It is collected by piercing the veſſicles of the bark of the tree which is very abundant in the mountains of Switzerland. It may be uſed for the ſame purpoſes as the preceding.

F. Pitch is the reſinous juice of a kind of fir named Picea. It is extracted by inciſions made in the bark of the tree; it is melted by a gentle heat,

heat, ſtrained through a ſack, and received in caſks, where it conſtitutes Burgundy pitch or white pitch: when mixed with lamp-black, it is black pitch. By long fuſion it becomes dry, brown, and forms colophany. The coarſer parts are burned in an oven, which has a chimney terminating in a ſmall receptacle ending in an iron pipe. In this laſt the ſmoke becomes condenſed, and forms a fine ſoot called lamp-black.

G. Galipot is the reſin of the pine, which affords ſweet kernels. This tree is tapped towards the lower part of the trunk, and the reſin flows into veſſels placed to receive it. Other inciſions are made when the former ceaſe to exſude. When it flows out in a fluid ſtate, it is called *galipot;* that which dries on the tree in yellowiſh maſſes is called *barras.* Thoſe juices are liquified in boilers, and ſtrained through ſtraw mats. This maſs, caſt into pieces or loaves, in excavations made in the ſand, is called in French *arcançon,* or *brai ſec.* If water be interpoſed, the matter becomes white, and forms reſin or pitch reſin. The Provincials diſtil the galipot in the large way, and obtain an oil which they call *huile de raze.* Tar is prepared with the trunks and roots of the pine of which it is the empyreumatic oil. The branches of the tree are heaped up, covered with turf, and ſet on fire. The oil diſengaged by the heat not being capable of exhaling through the turf, is precipitated

pitated into a veſſel by means of a gutter, whence it is laded out, and ſold under the name of tar.

H. Tacamahaca, gum elemi, gum anime, are little in uſe. The tree, which affords the firſt, is not known; the elemi comes from a ſpecies of amyris; the oriental gum anime, or copal, of which the origin is unknown; the occidental anime, or courbaril, which flows from the hymenæa, a tree of South America, are employed in varniſhes.

I. Maſtic has the form of white tears of a faint ſmell; it flows from the turpentine tree and the lentiſc. It is uſed as an aſtringent and aromatic, and is an ingredient in drying varniſhes.

K. Sandarac has the form of white tears more tranſparent than thoſe of maſtic. It is obtained from the juniper between the bark and the wood; it is alſo called varniſh by ſome, becauſe it is much uſed in thoſe preparations. It is moſt generally known in its application upon paper, where eraſures have been made in order to prevent the ink from ſpreading.

L. The reſin of gayac, or gum gayac, which is greeniſh, is employed againſt the gout; it flows from the gayac by inciſions. Many chemiſts conſider it as a gum reſin.

M. Ladanum, or the reſin of a ſpecies of ciſtus in the iſland of Candia, is of a blackiſh colour. The peaſants collect it with a rake, to which are ſuſpended a number of ſtraps of leather, which they paſs in contact with the trees; they form cylindric

cylindric portions, which are called *ladanum in tortis*. It is adulterated by much black sand. It is employed as an astringent, and is the most impure and most ponderous of the resins.

N. Dragon's blood is a red juice obtained from *Dracæna draco*, and many other vegetables. It has the form of flattened or rounded masses, or of small spheroides, or olives covered with leaves of reeds and tied together. It is used in medicine as an astringent.

18. It is not unusual to preserve in collections, sometimes under the name of gums, a continued series of different resinous juices of Africa, America, and India, which are not used in Europe, and of which it is unnecessary to speak in this place. They are known to be resins by their fusibility, their inflammability, their insolubility in water, and their solubility in alcohol.

F. *Uses.*

19. In the rapid enumeration here presented, respecting the most common species of resins, we have seen that these juices, most of which are particularly consecrated to medical use, are very far from possessing all the virtues commonly attributed to them. Their external application is the most beneficial and the best known with regard to its antiseptic effects.

20. Many of them are more or less useful in the arts as combustibles. Some nations use it

for

for the purposes of combustions or illuminations, and they are employed in embalming and perfuming. The art of painting derives great advantage from them; they are the basis of varnishes, particularly that which is named Chinese varnish. They afford oils of great value for painting and for ship-building; pitch, tar, and lamp-black, are the products of these substances; and in a word, there are few materials which are more eminently useful.

Article XVI.

Concerning the Thirteenth of the immediate Materials of Vegetables, namely Gum Resins.

A. *Situation.*

1. THE name of gum resin is given to certain inflammable juices partly soluble in water, partly in alcohol, which are thought to be natural combinations of resins, and mucilaginous extractive matters.

2. These juices are contained in the proper vessels of a great number of vegetables, none of their parts being deprived of them; or rather they are found in the roots, the stems, the leaves, the flowers, and the fruits of many plants.

3. We must nevertheless observe, that these two last kinds of organs, the flowers and the fruits,

fruits, are most commonly without the substance, as also are the seeds, and that it is most particularly found in the roots, the stems, and the leaves. These three classes of vegetable parts are in fact those in which Grew, Malpighi, Bonnet, and Duhamel, found the greatest abundance of proper vessels frequently placed in assemblages beneath the bark, or in the first ligneous strata.

B. *Extraction.*

4. THERE is this very sensible difference between resins and gum resins, that the latter being included in the proper vessels, are never extruded from the plants; whereas the resinous juices flow spontaneously on the surface of vegetables, where they dry and become condensed in the form of brittle tears. The gum resinous juices, on the contrary, being concealed in the inner parts of plants never flow out, and art alone can extract them from the channels in which they are contained.

5. When the texture of a recent vegetable is broken in those parts which contain gum-resinous juices, they issue forth in white, yellow, or variously-coloured drops always opaque or milky, resembling emulsive fluids. If the parts charged with these juices be pressed, or if, after having collected a sufficient quantity by the slight efflux which follows their incision, by receiving the same from a large quantity of ve- getable

getable matter, at the fame time this juice may be condenfed by the rays of the fun, and the elevated temperature of a hot climate, fuch as favours the vegetation of this genus of plants. In this manner the gum-refins are obtained.

6. Such is the general procefs which is followed to procure them. The vegetables which contain them are cut or notched when full of juice; the juices are collected by leaving the vegetables to emit the opaque fluid they contain; this is expofed in a thin ftratum to the rays of the fun in Africa, America, or the Eaft-Indies; where it condenfes, evaporates, and becomes thick, and at laft dry. It is in this complete ftate that the gum-refins are met with in the market.

C. *Phyfical Properties.*

7. The gum-refins, extracted and prepared by the means here pointed out, are folid brittle bodies, almoft always opaque, in irregular tears or fragments often adhering to each other, or by means of a pafte which connects them together. Moft of them have a confiderable odour ufually of a fetid or garlic fmell, with an acrid difagreeable, bitter, and naufeous tafte.

8. Their colour in the different fpecies is fingularly varied; but a yellow rufty colour is generally predominant. They are not in general proper electrics, like the refins, nor do they equally well intercept the courfe of the electric

 fluid.

fluid. They are not fusible in the same manner by heat, and they become changed instead of flowing like them by the action of heat.

D. *Chemical Properties.*

9. THOUGH few chemical experiments have yet been made upon these substances, except certain very incomplete analyses, and no truly connected researches have been made upon the gum resins, there nevertheless exist in the midst of the assays of pharmaceutic operations upon these bodies some general phenomena which may serve as characters to distinguish them from the other immediate materials of vegetables, and which may be considered as properties belonging to the whole genus: the following may be considered as generic qualities.

10. All gum resins burn, dry, swell and emit fetid vapours without taking fire: at first when heated upon burning coals they afford by distillation, besides the volatile oils, ammonia combined with an acid, and leave a voluminous saline charcoal. They also afford much carbonic acid gas by distillation.

11. They all unite with water by trituration; and form a kind of emulsion, or milky turbid liquor, which by the action of fire or of the air deposits a portion of resin, and retains in solution a substance rather extractive than gummy or mucilaginous. Their solution in water is frequently acid. The concentrated sulphuric acid decomposes

decomposes and carbonates them. The nitric acid converts them partly into oxalic acid. The weak acids dissolve them, and the acetous acid has long been considered as their specific solvent.

12. The alkalis have not the same inactivity with regard to the entire gum resins as with respect to the true resins; and when in pharmacy these substances are used to dissolve, as it is pretended, the resin by boiling woods or barks in water---it is not the resinous principle which the alkalis thus abundantly take up, but the portion of extractive matter oxigenated and become insoluble, as I have elsewhere shown; that is to say, a true gum-resinous matter, for this extractive matter being united to the alkali in that case, carries with it a small portion of resin. The same observation is applicable to magnesia, when employed to the same purpose.

13. Among the immediate materials of vegetables, which have some action upon gum-resin, we must reckon the mucus, sugar, and non-oxigenated extractive matter, which render it either soluble in water, or miscible in that liquid, as all the pharmaceutical operations prove which are used for the medical administration of this substance.

E. *Species.*

14. The gum-resinous juices are extremely numerous in plants, and may be distinguished into

into an immenſe variety of ſpecies; but we do not in this place treat upon more than thoſe which are moſt generally known and employed either in medicine, where they are conſiderably uſed, or in the arts.

A Olibanum or *incenſe* has the form of yellow tranſparent tears, of a ſtrong and diſagreeable odour when burned. It flows on the banks of the red ſea, from a kind of juniper or *thurifera*. By heat it affords volatile oil, an acid liquor, and leaves charcoal, owing to the extractive part it contains. In medicine it is uſed for attenuant fumigations. Notwithſtanding its name, this is not the gum-reſinous body which is burned as incenſe, for its odour is acrid and fetid; we ſhall ſee that the balſams are employed for that purpoſe.

B. Galbanum is a fatty juice of a brown-yellow, and nauſeous odour. It flows in Syria, in Arabia, and at the Cape of Good Hope, from inciſions made in a ferulaceous plant called by Linnæus, *Bubon galbanum.* Its ſmell is manifeſtly that of garlic. When diſtilled by naked fire it affords a blue volatile oil, which becomes red by keeping, together with an acid liquor and an heavy empyreumatic oil. It is a very good attenuant, and a powerful antiſpaſmodic, and is an ingredient in many plaſters and unguents.

C. Scammony is of a blackiſh-grey colour, of a ſtrong and nauſeous ſmell when pounded or heated, and of a bitter and very acrid taſte. We diſtinguiſh that of Aleppo, which is the pureſt, in in contorted fragments, covered with a grey homogeneous powder; and that of Smyrna, which is heavy, black, and mixed with foreign subſtances. It is extracted from the Convolvulus of Linnæus. The root of that plant cut and expreſſed on the place or in the earth, affords a pale juice, which is collected in a cavity formed in the lower part of the root, and which becomes black as it dries. Scammony contains a various quantity of extract or reſin, according to the different ſamples: in conſequence of which it produces very different effects in different patients. It is uſed as a purgative in the doſe of two or three decigrams to ſix or eight; when mixed with a mild extract, ſuch as that of liquorice, it forms the common diagrydium; and for this purpoſe alſo the juice of quinces is uſed. It is commonly adminiſtered by trituration, with ſugar and ſweet almonds, in the ſtate of an emulſion. We are not yet in poſſeſſion of a good analyſis of this gum-reſin, which is much employed in medicine, as well as moſt of the gum-reſinous juices.

D. Gum guttæ or gamboge has the form of cylindrical maſſes, hollow in the middle, fluted without, of an orange-yellow colour without ſmell, but of a very acrid and corroſive taſte. It comes from Siam, China, and the iſle of Ceylon. It is extracted from a large tree which is little known, but denominated Coddam in the country, and Cambogia by Linnæus, who placed it in the polyandria monogynia. It is diffuſible in water, in which it forms a kind of yellowish emulsion; its acrid property appears to be owing much more to the extract than the resin which it contains; it is strongly purgative in the dose of from two decigrams to four or five: It must not be employed internally without the greatest caution: the alkalis greatly diminish its acridness. Painters use it much as a fine golden-yellow pigment; it mixes very well with fixed and volatile oils.

E. Euphorbium is in yellow tears, worm-eaten or corroded, in small contorted cylinders, full of holes, of a caustic taste, and without smell. It flows from incisions in the euphorbium, in Lybia and Mauritania; it is collected round the thorns of this plant, upon which it becomes condensed and formed. It contains a very acrid resin, and is so strongly purgative, that it is reckoned among the poisons: It is seldom employed but externally in mortifications, of which it stops the progress, or as a detergent in ulcers.

F. Assa foetida is sometimes in yellowish tears, and most frequently in masses formed of various parts agglutinated together, of a rusty colour, shaded with different degrees of yellow. Its garlic smell is extremely fetid, and its taste bitter, nauseous, and disagreeable, is sufficiently distinguished among all the other gum resins. It is extracted from the root of a kind of ferula, which grows in Persia, in the province of Chorasan, and which Linnæus has denominated assa foetida. The root of this plant is fleshy and succulent;

ſucculent; it affords by preſſure a white juice of an abominable ſmell, which the Indians uſe as a condiment which they call food of the Gods, a very ſingular contraſt with the name of Stercus Diaboli, which is given to it in Europe. When diluted in water, aſſa fœtida oppoſed by this name to that of aſſa dulcis, formerly given to benzoin, forms a kind of milk or turbid liquor of a ruddy white, and very expanſible odour, which infects a great ſpace. It is internally uſed as a powerful antiſpaſmodic, and applied externally as a diſcutient.

G. Opoponax is a gum-reſinous juice in irregular plates, of a dark or ruſty yellow, ſtrong garlic fetid ſmell, with an acrid, bitter, and very diſagreeable taſte. It is extracted from the paſtinaca opoponax of Linnæus, in Perſia, in Turkey, and even in ſome hot countries of France and Italy.

This juice is ſuppoſed to contain equal parts of extractive and of reſinous matter. It is uſed in medicine as an attenuant, and enters into the compoſition of ſeveral plaſters.

H. Bdellium is a browniſh juice, ſuppoſed to be very analogous to galbanum. Its origin is not known. Enlightened botaniſts conſider it to be very different from that of the ancients, which was highly eſteemed.

It is thought to be compoſed of nearly equal parts of extract and of reſin. It has leſs taſte and ſmell than galbanum, and is manifeſtly inferior to it in virtue. It is at preſent ſcarcely at all employed

employed in medicine, though it ſtill conſtitutes an ingredient in ſome pharmaceutic compoſitions.

I. Sagapenum is gum-reſinous juice in white, yellowiſh, or ruſty tears, of a diſagreeable and inſupportable ſmell when thrown on lighted coals. Its taſte is acrid, bitter and repulſive. It comes from Egypt, Perſia, and India; but the tree which furniſhes it is unknown.

In general this vegetable juice reſembles in its properties gum ammoniacum, galbanum, opoponax, &c. All the gum reſins having a garlic flavor appear to be proper juices of umbelliferous plants. Sagapenum is no longer particularly uſed.

K. Sarcocolla, a reſinous gummy juice, ſo denominated becauſe the property of cloſing wounds was formerly attributed to it, is known by its figure in ſmall grains reſembling thoſe of millet, of a white, yellow, or red colour. It has no ſmell, and its taſte is bitter and nauſeous. It comes from Perſia and Arabia, from an unknown vegetable: it contains more extract than reſinous matter. Its ſuppoſed virtues are no longer credited, and it is uſed only in a few compoſitions.

L. Myrrh is a concrete juice in reddiſh brilliant tears, frequently covered with a ruſty coloured powder, of a ſtrong but agreeable ſmell, with a bitter and rather aſtringent taſte, and preſent in their fracture, white lines of the form of a nail. Some of theſe tears are entirely gummy, inſipid

insipid and insoluble in water. It has the appearance of a mixture. Myrrh comes from Egypt, and particularly from Arabia, the ancient country of the Troglodites. The plant which affords it is unknown: it contains much more extractive and mucilaginous matter than resin. When it is pulverized and held for some time in the mouth, it softens and becomes white and ductile like wax. It is used in medicine as a very good stomachic, antispasmodic and strengthener. Cartheuser recommends it to literary men who have a delicate stomach, to chew and swallow it diluted in the saliva. It is used in surgery to cleanse ulcers, and to stop the progress of caries. It is employed in powder or dissolved in alcohol.

M. Gum ammoniac is sometimes in single tears, white within, and yellow externally, and often in masses resembling those of benzoin, formed of white tears, connected by a more coloured and adhesive juice. Their white colour and fetid smell easily serve to distinguish them from benzoin, which they considerably resemble. It is suspected that this gum-resin which comes to us from Africa, is obtained from an umbelliferous plant, on account of the seeds which are mixed with it; but we do not know the plant which produces it, the manner of its growth, nor the mode of its preparation.

The phenomena of the solution of this substance by water and by alcohol, and particularly its

its inflammability ſhow that it reſembles the reſino-extracts of Rouelle.

Gum ammoniac is uſed in medicine as a very good attenuant in obſtinate obſtructions. It is given in the doſe of a few grains in pills, or in emulſion. It likewiſe enters into the compoſition of a number of attenuant plaſters, as well as the other gums before deſcribed.

F. *Uſes.*

15. The foregoing account of the principal ſpecies of gum-reſins proves that their uſe is particularly applicable to medicine, and ſcarcely at all to the arts, if we except the ſlight employ which ſome of them have as pigments.

16. It is very remarkable that the gum-reſins are either purgative, draſtic, and even almoſt cauſtic, or elſe antipaſmodic ; ſo that they may be divided into two genera with regard to their medicinal properties.

Article XVII.

Concerning the Fourteenth of the immediate Materials of Vegetables; of Caoutchouc, or Elaſtic Reſin.

A. *Situation.*

1. CAOUTCHOUC, or elaſtic reſin, very improperly called elaſtic gum in the arts, is one of

of thofe vegetable matters of which it has been difficult, if not impoffible, to determine exactly the nature, fo far as to compare it with the other immediate materials, and to place it in the clafs either of refins or concrete fixed oils, which it refembles. By comparing all its properties with thofe combuftible matters, we foon difcover that it is a particular principle really different from every one of them, and that it is only remotely analogous to them. It is neither a fixed oil, nor a refin, nor a gum-refin, but a peculiar fubftance itfelf.

2. I place it as one of the immediate materials of vegetables, becaufe it appears that we can extract caoutchouc from various American trees; and that it is not peculiar to the juice of the hevæa of Aublet. Some botanifts, particularly travellers, affure us that elaftic refin is obtained from various trees of thofe countries, and that it is prepared by condenfing and evaporating the mixture of a number of thofe juices.

3. It is in an order of proper veffels that this white juice, refembling an emulfion and to that which the gum-refins afford, is contained. It appears to exift particularly under the bark of the hevæa. Some have apprehended that feveral lactefcent plants of our temperate climates, particularly fome fpecies of Euphorbia, might afford a fubftance analogous to caoutchouc; and though the firft affays have not yet produced an authenticated fuccefs, this view is far from being improbable.

B. *Extraction.*

B. *Extraction.*

4. In America, particularly in Guiana, incisions are made across the bark of the hevæa to its ligneous part. The white juice which flows out is received in a vessel. As the only intention for which it is collected is to fabricate vessels, or a kind of pear-shaped bottles, this juice is applied in layers upon moulds of dry clay: each layer is dried in the sun or by the fire, the smoke of which colours them of a deep fawn or brown colour. The successive application of these strata is continued until the vessels are rendered as thick and as strong as may be desired. The natives of the country employed in this labour terminate it by usually making designs or various engravings with points of iron. When the juice has become thick, concrete, and solid, the brittle earth which formed the mould is crushed, and shaken out in small fragments through the aperture of the vessel.

5. In this operation, the juice of the hevæa becomes concrete; but this is not effected, as has been supposed by the mere evaporation of its liquid part, or the water separated from the elastic matter. I have ascertained another cause of this separation, which is a true concretion. I examined the juice of the hevæa, which was sent me from the Isle of Bourbon or Reunion, as well as that of Cayenne and the Brazils. These

Thefe three juices might not perhaps be from the fame tree, but they exhibit exactly the fame properties with regard to the formation of the elaftic fubftance. Each contains a white turbid liquor, of an infupportable fetid fmell, in the midft of which is a white concrete matter, rather fpongy at its furface, very elaftic, of a foft, fine, and clofe texture, which was the true caoutchouc: in a word, very pure, and of a quality much fuperior to that of the utenfils prepared out of this fubftance in America. Thefe folid and elaftic concretions had the form of the bottles that contained them, but were lefs in fize: they had been depofited by time and without evaporation, for the bottles were very well clofed, and had loft nothing. The juice which was contained in them, when expofed to the air, became very fpeedily covered with a cruft of elaftic gum. I accelerated the formation and feparation by combining the action of caloric with that of the air. In a veffel filled with oxigen gas, the liquid afforded an elaftic pellicle more fpeedily, and a very fenfible abforption of gas took place. Alcohol feparated flakes, and the oxi-muriatic acid partially formed an elaftic precipitate.

6. From thefe experiments I have concluded that caoutchouc is ready formed in the juice of the hevæa, and is capable of being feparated in the concrete form; that a portion is neverthelefs not complete enough to be depofited with its

elaſtic property; that it appears to want only a ſmall quantity of oxigen to complete its properties; that in this manner the contact of the air, the oxigenated muriatic acid had acted upon this ſubſtance; and that the atmoſpheric oxigen influences the concretion and ſolidification of caoutchouc in the fabrication of utenſils which are made in the hot countries where the hevæa grows. From theſe notions I have propoſed to import into France the juice of the hevæa, by adding the cauſtic alkali which prevents the elaſtic ſubſtance from precipitating, in order that we might be able to fabricate all the proper utenſils, or to plunge moulds in the juice upon which it might ſpontaneouſly depoſit the caoutchouc in a much purer ſtate than the concentrated and thickened juice which is uſed one ſtratum after another.

7. We ſee alſo that the pureſt caoutchouc is that which is ſeparated in this manner ſpontaneouſly from the juice of the hevæa while kept in cloſe veſſels; that our experiments ought rather to be made upon this than upon the ready-formed veſſels in order to determine its nature, and that it may be highly uſeful to employ this white concrete juice ſo depoſited for the purpoſes to which it is adapted, and which I ſhall point out at the end of the preſent article.

C. Phyſical

C. *Physical Properties.*

8. Pure caoutchouc is white or ſlightly fawn coloured, extenſible, elaſtic, compreſſible, reſuming its original dimenſions as ſoon as the external force is withdrawn. Its texture is denſe, brilliant, fibrous, and ſmooth, like that of an animal ſubſtance; it is ſoft and becomes ſofter by heat, and by this ſimple proceſs it may be moulded into any deſired form. Cold deprives it in part of its properties.

9. Its ſpecific gravity to that of water is as 9,335 to 10,000. It has neither taſte nor ſmell. When cut, and the parts preſſed together, they unite ſo intimately that they cannot be ſeparated, but form an homogeneous ſolid. This valuable property is frequently uſed for connecting fragments and ſlips of this ſubſtance.

D. *Chemical Properties.*

10. Caoutchouc, expoſed to a violent heat, becomes ſoft, melts, ſwells up, emits a fetid odour, curls like ſome animal ſubſtances, and at length takes fire with a bright oily flame; from which property it is uſed in its native country for giving light, in the manner of a torch or flambeau. When heated in a ſilver ſpoon, it becomes converted into a kind of black oil, which remains greaſy and adheſive, though expoſed

for ſeveral months to the air, and never again aſſumes its elaſtic property. When diſtilled in cloſe veſſels, it affords a ſmall quantity of turbid water, charged with an ammoniacal ſalt not yet well known, a denſe brown oil, partly concrete and fetid, with carbonated hidrogen gas and carbonic acid gas. It leaves a ſpongy coal in little abundance, with very ſlight traces of ſaline matter, and difficult to be burned. By theſe products we may obſerve that it approaches to the gluten of animal matters.

11. No union is known between ſimple combuſtible bodies and caoutchouc. The air produces no alteration in it. Boiling water ſoftens it, ſwells it like a ſkin, gives it ſemi-tranſparence, but does not diſſolve it. Caoutchouc thus ſoftened is very ſoluble in ether, though it is not ſo in its natural ſtate. We are indebted to Pelletier for this diſcovery, who has ſolved the problem ſo long ſought reſpecting the ſolubility of Caoutchouc, announced by Macquer in 1768, but which all chemiſts have found either difficult or impoſſible until this explanation was given by Pelletier.

12. The powerful acids with ſimple radicals act upon caoutchouc. Concentrated ſulphuric acid reduces it to the coaly ſtate, and blackens it at the ſame time that itſelf becomes ſulphureous. The nitric acid attacks, corrodes, and renders it yellow like cork, changes it into oxalic acid, and a fatty matter. The other acids have no action upon it; the cauſtic alkalis do not alter

it,

it, nor reduce it to the ſaponaceous ſtate, which proves that it does not truly reſemble the fixed oils. The ſalts do not attack it, nor change its properties. The action of the oxides and metallic ſolutions upon theſe bodies have not yet been examined.

13. Among vegetable matters, the oils are the only ſubſtances which have an evident action upon caoutchouc. Fixed oils boiled upon this ſubſtance diſſolve it, as they alſo do melted wax; but it remains adheſive and viſcid in the ſolutions. The oils of lavender, aſpic, and turpentine diſſolve it by the aſſiſtance of a gentle heat; but the viſcid combination remains adheſive, incapable of drying, ſticking to the hands, and in fact of no utility. By the mixture of fixed and volatile oils it is diſſolved, in order to form that fat and flexible varniſh which is laid upon ſilk. A ſolution of caoutchouc in oil of aſpic, mixed with alcohol, throws down white flocks, inſoluble in hot water, which remain at the ſurface of this laſt fluid, and become white and ſolid like wax by cooling. Berniard, to whom we are indebted for this experiment, thinks that it precipitates a true concreſcible fixed oil; but this aſſertion is far from being ſufficiently accurate to be conſidered as well eſtabliſhed.

 E. Species.

E. *Species.*

14. We are not yet acquainted with many ſpecies of caoutchouc, though it is probable there may be ſeveral different from each other, if not from their chemical characters, at leaſt with regard to their origin. From what has already been ſtated, we know that there is a white and pure caoutchouc depoſited from the juice in cloſed veſſels, and an impure caoutchouc dried in the air and in the ſmoke; but the latter differs from the former only in certain impurities which change it, and of which it is poſſible to deprive it by the ſucceſſive action of water, air, and of alcohol, aſſiſted by heat.

15. When we ſhall be better acquainted with the hiſtory of the different trees which are capable of affording caoutchouc, and when their products ſhall have been comparatively examined, we ſhall be able to diſtinguiſh, if not the ſpecies, at leaſt the modifications and varieties of this juice, and we ſhall then know whether we may hope to diſcover, in the plants and trees of our temperate climates, any materials capable of affording to the arts a ſubſtance of a ſimilar nature.

F. *Uſes.*

16. We may eaſily conceive that a hard, ſolid body, unchangeable in the air, inſoluble in wa-

ter,

ter, not attacked by the greater part of the solvents, and which, to these valuable qualities, joins the still more valuable quality of being powerfully elastic, must present a great number of important uses to the arts: in medicine it is employed for the fabrication of bougies, pessaries, bandages, and a great number of surgical utensils, proper to diminish or even to cure a great number of disorders. We must observe that all these utensils are capable of becoming soft, and extended by the heat and contact of animal humours, and consequently that it is necessary to attend to this property, in order to give such a form to the article in question as may admit of the augmentation of volume they undergo. In order to make catheters of pure caoutchouc, this substance, softened and swelled by water, is dissolved in ether, and its solution applied in successive layers upon moulds of wax, which are afterwards melted out in boiling water.

17. In countries where the trees which afford this solid, elastic and inflammable juice grow, flambeaux and torches are fabricated, which serve to give light, and also vessels and instruments applicable to many uses. Those vessels retain water and various liquors very well, and communicate neither taste nor smell to them. Boots and shoes are made of it, which are very durable, and yield to the motion of the parts.

18. In Europe, the bottles or vessels of caoutchouc which are imported and cut into pieces

or

or stripes, are used to efface lines of black-lead pencils, and also for garters, for elastic re-action-pieces in machinery, and particularly for instruments of natural philosophy and chemistry. It is dissolved in oily mixtures, to be applied as a varnish impenetrable to water upon silk for the purpose of clothing, or the construction of aerostatic machines. But most of these varnishes have the inconvenience of softening and becoming very adhesive when exposed to the rays of the sun or to heat.

Article XVIII.

Concerning the Fifteenth of the immediate Materials of Vegetables; Balsams.

A. *Situation.*

1. BUCQUET was the first chemist who distinguished, in 1774, the natural balsams from the resins and gum-resins, by considering as such the resinous juices which are constantly united to an acid, namely, the benzoic acid, and by giving them as proper characters, that of affording this concrete acid by sublimation with the action of fire, and giving acidity to water, in which they were fused and boiled for a certain time. This denomination so determined, at last fixed the value of the term, which was till then vague

vague and uncertain, becaufe it was before attributed to refinous juices, as well on account of their liquidity as their fragrant and agreeable fmell, and alfo to oily and alcoholic compounds, to which this property was communicated by the mixture of feveral matters more or lefs odorant. It is with fo much more propriety attributed to bodies of this genus, becaufe the aromatic volatile acid they contain gives them a lively fmell.

2. All that has been faid refpecting the properties of volatile oils, leaves no doubt refpecting the acidifiable characters of thefe fubftances, and confequently their origin and the formation of natural balfams, becaufe thefe appear in fact to be merely volatile oils, of which the oxigenation has converted part into refin, and part into acid: and accordingly thefe matters appear to poffefs the fame fituation in vegetables as thofe oils; and though the natural balfams are yet little employed and known but in a fmall number, the number is fufficient to confirm this notion, and to allow us to regard thefe products as exifting in many of the parts of vegetables.

B. *Extraction.*

3. We have yet few accurate notions refpecting the manner in which moft natural balfams are procured. We fee neverthelefs by the example of the balfam of Peru, that thefe matters flow from trees in the foft and vifcid form of turpentine, fince they are collected in entire cocoa-

cocoa-nut ſhells, in which they become condenſed and ſolid.

4. When we ſhall be more intimately acquainted with the great number of vegetables that contain balſamic juices more or leſs concrete, and volatile oils converted into reſins or acids, we ſhall be able by applying proper ſolvents or more particularly alcohol, to obtain thoſe immediate products, and increaſe the claſs of materials ſo important for the arts. This practice is already conſiderably advanced, without a proper attention to the progreſs of the ſcience, by treating ſeveral vegetable matters with alcohol, which, as we ſhall ſee in the expoſition of theſe ſpecies, are really charged with balſam. A kind of ſolid balſam is fabricated by condenſing in the air, or by heat, ſuch volatile oils as are moſt diſpoſed to acquire this ſtate of reſin or of acid.

C. *Phyſical Properties.*

5. The balſams can never be as liquid and as light as the volatile oils, becauſe they are always produced by an alteration in theſe laſt. They are therefore condenſed viſcid juices, flowing with ſlowneſs and difficulty, ſpeedily aſſuming the concrete form of a brown or ruddy colour, of an agreeable aromatic ſmell when compreſſed, rubbed or heated, and particularly when perforated with an ignited pin.

6. Their ſpecific gravity lies between 1, 1 and 1,0. They all exhibit an acrid and ſtrong ſmell

ſmell when maſticated for a time. They redden blue vegetable colours when their powder is mixed with thoſe colours diſſolved in water. When heated they melt, and ſoon exhale a white vapour of a very ſtrong and penetrating ſmell. By cooling after fuſion they preſent on their ſurface a white needled or ſnowy powder. The heat which fuſes them produces alſo a partial decompoſition.

D. *Chemical Properties.*

7. All the chemical properties of the natural balſams ſhow that theſe ſubſtances are compounds of reſins and benzoic acid. Many of theſe properties being analogous to thoſe of the reſins, we ſhall inſiſt only upon ſuch as are proper to diſtinguiſh them, and which are owing, as we ſhall ſee to the preſence of benzoic acid in theſe juices.

8. When they are heated ſtrongly with the contact of the air, they afford during their fuſion and ſwelling up, a very odorant white fume, of a ſharp acrid ſmell, exciting cough and tears, which when diffuſed in the air, communicates an agreeable perfume. It is the true incenſe. When heated in cloſed veſſels, the ſubſtance of this vapour becomes condenſed in cryſtalline needles, or plates, of an acrid nature. In a word, we obtain the benzoic acid of which I have fully treated in one of the preceding articles, and which amounts to one fifth of their weight.

After

After having afforded this product, the residue is simply a resin.

9. In the air they are not liable to change, though exposed in a dry and concrete state; if they be still soft they dry and sometimes suffer a small portion of their acid to exhale, when the air is very hot, which effloresces on their surface, and covers them with a powder resembling snow or small white needles, which have been called the flowers of certain substances.

10. The water in which they are boiled softens and fuses them, and dissolves part of their acid, which may even be obtained separate and crystallized by cooling, as Geoffroy first showed at the commencement of the eighteenth century; but we cannot obtain by this means more than a small portion of their benzoic acid; the greatest part remaining fixed and enveloped by the fused resin: so that we cannot have an accurate analysis by this process, which merely proves that the balsams contain a concrescible and volatile acid.

11. The acids do not act upon the balsams; the alkalis seize their benzoic acid and form soluble benzoates. Lime is more particularly employed to attract the acid, after the manner of Scheele, as I have already observed in the article of acids.

12. The balsams are soluble like the resins in oils, particularly volatile oils, and form solutions of different degrees of density and viscidity, which are frequently prepared for pharmaceutic uses.

E. Species.

E. Species.

13. I HAVE already obferved that more vegetable balfamic fubftances exift than are reckoned in the materia medica. Hitherto we have known only benzoin, the balfams of Peru and Tolu, which are confounded together, and ftorax, to which muft be added the common ftorax of the fhops, as a variety of ftorax. I add to thefe well-known fpecies the balfam of Vanilla and that of Canella, becaufe thefe two fubftances contain volatile oil and benzoic acid, in the proper condition to form true balfams.

A. Benzoin: two forts are diftinguifhed, the benzoe amygdaloides, formed of white tears refembling almonds, connected by a brown cement. It refembles our *nougat.* Common benzoin is brown, and without tears: it emits a very pleafant odour when fufed, or when punctured with a heated needle. The tree which affords it is little known. Driander calls it ftyrax benzoifera. Murray however obferves that the bark of the wood of this tree emits the odour of benzoin even when burned. According to him it is very doubtful whence this balfam comes.

Benzoin is exported from the kingdom of Siam, and the ifle of Sumatra. It affords very little volatile oil on account of its folidity. Boiling water extracts an acid falt in needles, of a ftrong fmell, which cryftallizes by cooling; it is alfo obtained by fublimation, and was formerly called flowers

flowers of benzoin. This operation is made in two glazed earthen veſſels, one above the other, and luted together with paper. For this purpoſe a very gentle fire muſt be applied, otherwiſe the ſalt will be brown. The paper cone which was formerly uſed for this purpoſe ſuffers much of the concrete acid to eſcape. I have ſhown the properties of this acid in one of the preceding articles. Benzoin afterwards diſtilled by the retort, affords a very acid phlegm, a portion of concrete and brown acid, brown and thick oil, and a coal which remains contains a ſmall quantity of pot-aſh, and ſome traces of alkaline and calcareous ſalts.

Benzoin is ſoluble in alcohol, and its tincture precipitated by water conſtitutes the lac virginale. The ſalt of benzoin or benzoic acid is employed as a good detergent in pituitous diſorders of the lungs or the reins. Its oil is diſcutient, and is externally uſed for paralyzed limbs, &c. Benzoin in a crude ſtate is uſed as incenſe.

B. Balſam of Tolu. This comes to us in yellowiſh tears, or in a fluid ſtate. It flows from the toluifera, placed by Linnæus in the claſs of the decandria monogynia. We receive it from South America, between Carthagena and *Nombre-de-Dios,* which the iſlanders call Tolu, and the Spaniards Honduras. It affords by analyſis the ſame products as benzoin, and particularly a concrete acid ſalt; it is uſed in diſorders of the lungs, and is made into a ſyrup.

C. Balſam

C. Balsam of Peru: modern naturalists distinguish balsam of Peru from that of Tolu. It flows in fact from a different tree, and comes to us in reddish tears, or else inclosed in cocoa-nut shells. It is extracted by plunging those shells in boiling water, which softens it, and causes it to flow out. It presents the same chemical properties, and is applied to the same uses as the preceding balsam. Its smell is somewhat different when immediately compared with that of balsam of Tolu.

D. Storax is a solid balsam, in red dry tears, or else brown and adhesive: it has a very strong smell. It flows from the oriental liquid amber, a plant little known. Duhamel observed a juice of the same smell flow from the aliboufier. Neumann analyzed pure storax, and obtained very little volatile oil, a concrete acid salt, and a thick oil.

Its use is similar to that of benzoin; it is especially employed for perfumes.

Formerly it was imported enclosed in reeds, on which account it received the name of *styrax calamita*: at present it is brought to us in the form of cakes, or irregular masses, of a reddish-brown colour, mixed with some tears of a lighter tinge, and of a very pleasant smell.

The common styrax, employed for the preparation of the ointment which bears its name, is a liquid juice proceeding from the same tree as the storax; it is the grossest and most impure part of the liquidambar; it contains much impurities

purities, and portions of bark. Citizen Bouillon-la-Grange has made a chemical examination of it; he has found that it becomes clotted, and much ſwelled by the action of the fire; that much of it is loſt in attempting to purify it by fuſion and ſtraining, as has been propoſed in pharmacy. He has extracted benzoic acid from it in conſiderable abundance by means of lime; has propoſed to purify it by means of alcohol, and to employ it thus purified for the preparation of the ointment. When obtained by this proceſs, it aſſumes moſt of the properties of true ſtorax.

E. I admit a balſam of vanilla, though it is not yet known, and has not been extracted, becauſe benzoic acid may be volatilized from this legume, and becauſe it contains a reſin in conſiderable abundance. By treating vanilla with alcohol, and afterwards evaporating its alcoholic ſolution or tincture, this balſam will be obtained, which will preſent the characters of ſtorax.

F. I can ſay the ſame of cinnamon, as it affords volatile oil in abundance by diſtillation, and as its diſtilled water depoſits cryſtals of benzoic acid by cooling. There is reaſon to believe, that by treating cinnamon with alcohol, and evaporating the ſtrong tincture thus obtained, a real balſam of cinnamon will be extracted, brown, odorous, fuſible, affording benzoic action by the fire, &c.

F. *Uses.*

14. THE balsams, as we have seen, are much employed in medicine. They are still more employed in perfumes; for the latter use, they are made up in all sorts of forms. They prevent and retard the putrefaction of animal matters, and are extremely useful in embalming, which derives its name from them. Sometimes the perfume is combined with alcohol and sugar, in preparing *liqueurs* for the table, &c.

ARTICLE XIX.

Of the Sixth of the immediate Materials of Vegetables; colouring Matters.

A. *Situation.*

1. THE coloration of vegetables, and of their different parts, is one of the most beautiful phenomenona which the vegetable economy presents. It has at all times excited the attention of philosophers, and they have been incessantly engaged in investigating its cause. Chemists have believed, after a multiplicity of researches, that it proceeds from a particular matter, which they have denominated *colouring principle;* but they soon found that this pretended

pretended principle, inftead of being identical and conftant, was very much varied in its properties, and ought not to be confidered as always one and the fame matter. Were it even well proved, what the great Newton has advanced, that the different coloration depends upon the diverfity of the furfaces, and the manner in which each of thefe furfaces reflects or refracts the rays of the light, it would immediately refult that the very difference of the external furfaces of thefe bodies muft imply a difference in the texture and compofition of each of them. Thus from the mere circumftance that the colours and the different parts of vegetables are very much varied, it follows that this variety itfelf muft be neceffarily connected with that of their nature: which evidently proves that no identical colouring principle can be admitted in plants.

2. The flighteft obfervation of vegetables proves that, befides the green colour which is generally diffufed throughout their foliage, their different parts are tinged in a very different manner; that none of them entirely refembles another in this property, and that the feat of what are called colouring parts is diffeminated throughout all their organs, almoft with a kind of indifference, which fhows that this property of the coloration itfelf is, if I may ufe the expreffion, of very little expenfe to nature, and that it is as it were the neceffary confequence of all the phenomena of vegetation.

3. However,

3. However, the fame obfervation, though hafty, is equally fufficient to fhow that the contact of the light has fo much influence upon the formation of the colouring parts, that it feems even neceffary for their production. The barks, from the epidermis to the cortical layers, are conftantly more coloured than the interior of the trunks and of the trees. The leaves, as they are unfolded out of their buds, are of a pale green colour, which gradually darkens in proportion as they develop themfelves in the air; thofe that unfold themfelves in the fhade are white and infulated like the ftalks or the branches. At the moment when the flowers open or protrude themfelves out of the calixes in which they were folded up or enclofed, they are for the greater part without colour, and acquire a tinge only in proportion as they are expofed to the air and to the fun. However, it feems that an exception is found to this rule, when we fee the roots and fruits prefent even in the interior of their texture, which is always deprived of light, in fome inftances a very marked coloration; and it is frequently in the profoundly hidden parts that the moft beautiful and moft durable colours are found for the art of dyeing. The force of this objection is diminifhed when we obferve that thefe coloured roots and fruits belong in general to vegetables that have been long immerfed in light, that grow in latitudes where the rays of the fun ftrike them vertically, that have a ftrong and

durable vigour in their vegetation, and in which confequently the influence of the luminous principle penetrates even into the moft intimate and moft remote organs of their ftructure.

B. *Extraction.*

4. Since the colouring matters muft be acknowledged to be more or lefs numerous and different from one another, it is evident that the means of extracting them muft vary according to their nature. I do not fpeak here only of the coloured parts of vegetables which, in their mafs, require only to be feparated from thofe that are not coloured, and which need only be forted and collected, or mechanically feparated from each other. Thofe are only the refervoirs of the colouring matters; they are only furfaces, moft frequently hard and ligneous, to which the true colouring parts are glued as it were, and adhere like varnifhes. They require to be feparated or detached from thefe furfaces.

5. This feparation cannot be effected by mechanical means, becaufe the colouring matters are of an extreme tenuity, and moft frequently in a ftate of fuch drynefs, and at the fame time adhefion to the parts which they cover, and in fome fort decorate, that it is only by chemical proceffes that we can fucceed in feparating them. Recourfe is almoft always had to different folvents, according to the diverfity of thofe matters. Cold or hot water,

ter, long ebullition, ſometimes the alkaline matters or other re-agents applied to theſe coloured vegetable bodies, are the principal means that are put in practice, as well in chemical operations, and with a view to examine their nature as in the proceſſes of dyeing, and with the intention of afterwards applying the colours to the threads, the textures, and the ſtuffs deſtined to receive them.

6. Sometimes the vegetable colouring part is diſſolved or diluted in vegetable liquids and then they need only to be extracted by preſſure; but this caſe ſcarce ever obtains, except with the green colours and the fecula, which are their vehicle; and though it is frequently obſerved by the chemiſt in his experiments, it but very rarely preſents itſelf to the dyer in his practice. And even with the chemiſt himſelf, it is of all the circumſtances relative to the extraction of the vegetable colouring parts, the leaſt frequent; for it has really no application, except for the green colours.

7. There are many circumſtances in which the chemical art is not confined, as to the preparation of theſe colours, to the extraction of theſe matters from the vegetable ſubſtances which contain them; it frequently extends itſelf even to the proceſſes for modifying or actually forming them, either by a ſeries of ſpontaneous alterations of which they are ſuſceptible by fermentation and agitation in the air, or by mixing them with different ſubſtances which, whilſt they render them more ſoluble, mo-

dify them, and caufe them to pafs into the ftate which the art requires. It is in this manner that the fecula of the indigo plant and of the paftel is made to pafs from the green into the blue ftate, the grey or fawn-coloured powders of the lichens into the brilliant red of the archil, &c.

C. *Phyfical Properties.*

8. In treating of fubftances fo various and fo numerous as the colours of plants, it is impoffible to occupy the mind with any other properties befides their coloration itfelf; and this phenomenon alone prefents in itfelf a fufficiently beautiful feries of obfervations and gradations to merit fome particular confiderations. Amongft the multiplied varieties of colours with which the vegetables are adorned, we find that the green is the moft abundant and moft univerfally diffufed; and that this green, which inceffantly varies in its fhade, and which firft paffes from the pale to the deep green, afterwards undergoes a degradation in all vegetables, till it terminates in a more or lefs fixed and pronounced fawn-colour, which is known by the name of *dead leaf.* We afterwards find that the yellow is alfo one of the moft frequent vegetable colours, and at the fame time that it is the moft permanent and the leaft alterable colour that is known. We then fee

ſee the blue and the red alſo preſent themſelves in great abundance, and exhibit extremely varied tinges, the ſhades and qualities of which are no leſs intereſting to the eye than aſtoniſhing, on account of their inconceivable multiplicity. Finally, obſervation proves alſo, that amongſt the mixed colours, there are a multitude which reſult from the union or the mixture of two or more colouring matters; whilſt there are others of a ſimple and primitive compoſition.

9. The primary cauſe of the coloration of all bodies appearing to depend upon the different properties which theſe bodies have of reflecting different rays of light; it is of importance here to remark that the weakeſt reflection exhibits the blue rays approaching to black, that the yellow ray depends upon a more conſiderable re[illegible] the red is that which indicate[illegible] flexion. We may add to t[illegible] hat the ſame order ſeems to [illegible] ure in combuſtion and c[illegible] The moſt feeble combuſt[illegible] e light; a ſtronger inflam[illegible] light, and the moſt energ[illegible] white, the conſequence of [illegible] total reflection of the luminous rays. It ſeems that there is here alſo ſome analogy with the phenomenon of the oxidation of metals. The leaſt oxided are black or blue; as they become more oxided, they paſs into the yellow and orange ſtates; and when ſur-

charged

charged with oxigen, they become red and white. In the ſame manner, the colour of the maſſes of air is blue, as well as the light of the moon received upon white bodies, like that which ſurrounds the ſhade of bodies projected upon white ſurfaces. Whatever ingenuity there may be in theſe approximations, they however teach us nothing poſitive reſpecting the nature of the colouring parts, nor have they yet any exact relation with their chemical properties.

D. *Chemical Properties.*

10. Though according to the diverſities already announced in the vegetable colouring matters, it is really impoſſible to give generic characters which apply to them all; though it is evident that their exact hiſtory can only be ſpecific, it is however uſeful to ſeek amongſt the generality of their properties ſome of thoſe which, being more or leſs diſtinctly marked as characteriſtic of theſe ſubſtances, and not belonging to ſubſtances of another genus, muſt juſtly be conſidered as belonging excluſively to them. It is very evident that it cannot be in the ſame order which has been adopted for all the immediate materials hitherto treated of, that this table can be conſtructed; as they do not really reſemble any of thoſe materials, their chemical hiſtory muſt alſo be in a certain degree independent of them. The firſt chemiſts who

have occupied themfelves with the examination of thefe colouring matters, Hellot, Lepileur d'Apligny, Hecquet d'Orval, Mazéas, Macquer, and Poerner, have only committed errors, nor could they do otherwife. It is only fince the happy data of the pneumatic doctrine that Citizen Berthollet has begun to throw the greateft light upon this department of the fcience, and that Citizens Hauffman and Chaptal have alfo increafed our knowledge refpecting it.

11. It is particularly by the chemical attractions which the colouring vegetable matters exercife upon the acids, the alkalis, the earths, the metallic oxides, oxigen, and the textures, from wool to flax, that thefe matters are eminently diftinguifhed from the other vegetable matters, as Citizen Berthollet has firft fhown. Their attraction for alumine, and the metallic oxides, is fo great that they frequently feparate them from the acids, and are precipitated with them from their common folvent. Their union with thofe earthy or metallic bafes modifies their colours, frequently changes them, but renders them, on the one hand, more permanent than they were before, and lefs fenfible to the action of the air, and of the other external agents.

12. One of the principal and moft effential characters of the colouring parts, is their alterability and mutability by the contact of the air and of the light. In general, the oxigen is abforbed by thefe matters, which pafs into the yellow,

yellow, the brown, or the chefnut-red, according to the proportion of it which they contain. Many, at the fame time, lofe a portion of their hidrogen by a real flow combuftion; and then the predominant carbon efpecially contributes to make them pafs into a higher degree of coloration, and into cafts more and more intenfe. Thus, in general, all the vegetable colours experience this double effect from the action of the air; they abforb oxigen from it, and fuffer a portion of their hidrogen to be diffipated; in fuch a manner, however, that the confequence of the firft effect is in general a formation of red or brown tinges, and that of the fecond a perpetual tendency towards the black, towards the coaly ftate, towards one of the terms of the vegetable decompofition. The nitric acid, the fulphuric acid, and the oxigenated muriatic acid, act in the fame manner upon the colouring parts. I have made it appear, in a particular inquiry upon the vegetable matters diffolved in water, that all of them have more or lefs colour, that their coloration is augmented by the contact of the air and the abforption of oxigen; that determinate proportions of the latter produce certain fixed compounds at a certain temperature, the character of which is to have fuch or fuch a colour; that the *maximum* of this colouring oxigenation is, after having paffed through the reds and the browns, to produce the yellow, the moft conftant, the moft fixed, and the moft unalterable of the natural colours

lours of vegetables. Citizen Berthollet, on his part, has confidered the dark brown and black coloration by the contact of the air, as the product of a combuftion of the hidrogen, and of the denudation of the carbon,—as a kind of flow combuftion. He has fhown that the folidity, the fixity of the vegetable colours depend upon the greater or lefs difpofition which thefe parts had to experience this combuftion.

13. In proportion as the colouring matters experience the firft of thefe effects, or the abforption of oxigen, which combines entirely with them and changes their hue, they in general ceafe to be fo foluble in water as they were before; they even become entirely infoluble in this liquid; they at the fame time acquire folubility in the alkalis and in alcohol; they appear to approximate much to the nature of the oily matters, to hold a fort of middle rank between the refins and the fats, without however being exactly either the one or the other; they are what I have called the *oxigenated extractive*; for the greater number of the vegetable colours have the character of what has been defignated by the name of *extracts*. The fame is the cafe with thofe which have acquired darker colours by the lofs of their hidrogen, and the fuperabundance of their carbon; by becoming blacker they have become lefs alterable, lefs fenfible, lefs foluble, and it is even remarked that the colouring parts that are naturally the moft folid, the leaft changeable, the moft durable or permanent, owe

owe this property to the confiderable proportion of free carbon which they contain. Accordingly they are generally prepared by a preliminary and more or lefs advanced combuftion of their hidrogen, which takes place more efpecially in the fermentations which are employed for indigo, paftel, woad, &c.: it is on this account that thefe colours, though ftill fufceptible of being in fome degree changed by oxigen, are more capable of being diluted than diffolved.

14. The colouring matters unite eafily with the metallic oxides, and experience in the union which they contract with them, a combuftion proportionate to the quantity of oxigen which they can take from them; thus the colours of thefe combinations are, as Citizen Berthollet has remarked, a product of that which is peculiar to them and to the oxide, *plus* the oxigen added to the firft, and *minus* that which is taken away from the latter; for we muft calculate this double effect which modifies the colour of each of thefe fubftances. Hence the oxides with which oxigen has little adhefion, are the leaft proper for attracting and fixing the vegetable colouring matters, which they burn too ftrongly, as do thofe of gold, of filver and of mercury; thofe which yield too much of it, and experience great changes in their own colour, fuch as thofe of bifmuth, of lead and of copper, are alfo bad intermediates: the moft proper for attaining the object of fixing colours without altering them, are thofe which retain

tain the oxigen with force, and the colour of which is little changed by yielding a portion of it. Thus the oxide of tin, which has little adhesion with the acid solvents, and is strongly attracted by the colouring parts, giving them a basis of a beautiful white, which exalts their lustre whilst it weakens their tinge, has the greatest advantages in dyeing.

15. This simple theory explains the effect produced upon the solutions of the colouring parts by the metallic solution; and especially the precipitation occasioned in it by the super-oxigenated muriate of tin. There is some analogy between this effect and that of alumine; which unites very easily with the colouring matters, which frequently abandons its acid solvents to combine with it; which, by precipitating itself along with them upon the stuffs, favours their adhesion and stability, and which, by its pure white, renders their tinge clearer, whilst at the same time it stops the progress of their combustion, both in the fixation of the oxigen, and in the disengagement of the hidrogen. Such is the idea that ought to be formed of the action of the mordants. Amongst these, the astringent vegetable substance, especially that which is contained in the nut-gall, sumac, and the bark of the oak, the effect of which upon the stuffs so frequently serves as a preparation preliminary to the dyeing of them, is especially useful by its easy combustion and carbonization by the contact of the air, by the property of soon stopping

ping in its combuftion, and abforbing little oxigen, by its attraction for the matters of the textures, and efpecially of thofe that are of an animal nature, as well as to the different colouring parts, which it alfo attracts and firmly fixes upon the ftuffs, to which it communicates its own folidity. This is the reafon why galling is fo frequent and fo advantageous an operation in dyeing. The aluming, which is afterwards practifed, renders the colouring matter more adherent and clears it, efpecially when the precipitation of the alumine is favoured by the addition of the acetite of lead to the alum which it decompofes, forming acetite of alumine, the bafe of which is much more eafy becaufe feparated and precipitated, it adheres lefs to the acetous acid.

16. It has long fince been remarked that the colouring matters have a ftrong attraction for animal fubftances, that they feize upon thefe fubftances more quickly, and adhere to them much more ftrongly than to the vegetable fubftances. Thus wool and filk are the fubftances which take dyes the fooneft, and retain them the longeft, whilft flax and hemp are the moft difficult to be dyed. This appears to proceed from the circumftance that the colouring matters are of an order of compofition that approaches to that of the animal matters; they differ in fact from the gums, the fugar, the oils, the refins, the acids, by the prefence of azote, which forms one of their primitive principles, and it is

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to this that they owe the property of affording ammonia in their analyfis by fire; they approach in this circumftance to the nature of the extractive matter, in the hiftory of which I have pointed out the fame character, and of the ligneous fubftance, concerning which I fhall treat in one of the fubfequent articles. The colouring fubftance alfo adheres in general, or is found moft frequently under both forms in vegetables; and when authors attempted to give a chemical definition with regard to its properties and its nature, it has been confidered either as an extract, or as a ligneous fubftance.

17. Though what has hitherto been ftated concerning the chemical properties of the colouring matter, might fuffice to characterize it as a genus, and though the more ample details belong rather to the hiftory of its fpecies, I muft not however omit mentioning in this place, that before the modern difcoveries, which have led to the general confiderations which I have juft enumerated, chemifts, efpecially Macquer and Bucquet, had diftinguifhed thefe colours, which they already knew to be very much varied and very different from each other, into, a. *extractive* or *faponaceous colours*, entirely foluble in water, fo that they could not be precipitated upon the ftuffs unlefs by the action of the mordants which decompofe them; b. *refino-earthy colours*, the character of which was to melt and dilute themfelves only in water with the aid of heat, fo that they were precipitated from it by

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mere cooling, and adhered to the ftuffs which were kept immerfed in their baths; c. *refinous colours*, infoluble in water, foluble in the alkalis, and frequently in alcohol; d. *oily colours*, foluble particularly in the oils. But thefe diftinctions are too few and at the fame time too inaccurate; for they afford only a very imperfect idea of the diverfities of the colours, and of their true diftinctive characters, though it is indeed very difficult to give fuch as fhall be much more precife and fatisfactory.

18. There is another difference relative to the vegetable colouring parts, the inquiry into the caufe of which is of much greater importance, namely, that which relates to the nature of the coloration itfelf. In general only three primitive or principal colours are known in vegetables, namely, blue, yellow, and red; and there is reafon to believe that each of thefe primitive colours is a determinate combination of the principles which conftitute the colouring matters. Nothing is yet made out in the fcience refpecting the difference of thefe three colours: all that is known is, that of the three the yellow has in general the moft permanency and ftability; that the blues are much varied in their properties, that the reds lead to the brown and the black. We are confequently ftill more ignorant of the intimate caufes, or the multiplied combinations formed by the very numerous fhades of thefe three colours, the parents of all the reft.

E. *Species*.

E. *Species.*

19. THE hiſtory of the ſpecies is very truly, as I have already announced, that of the vegetable colouring matters, ſince theſe ſpecies, conſtituting a ſeries of real differences amongſt themſelves, require to be examined one after the other, and afford the only means which exiſt of drawing from their general compariſons the relations which they may have, and the characters by which they may be united as a genus. But this ſpecific hiſtory ſeems not yet to form part of the ſcience. As the whole belongs to the art of dyeing, it preſents, inſtead of a perfect knowledge of the vegetable colours, only a ſeries of proceſſes for extracting them, ſeparating them from their ſolvents, precipitating them upon the ſtuffs, cauſing them to adhere to them, and rendering them more or leſs ſtable, fixed, permanent and unalterable. It is not, however, the art which we are here to deſcribe; for this is altogether contained in that part of the ſcience which I deſignate by the word *application*, and muſt be treated after we have gone through the three firſt branches of the chemical ſyſtem. I muſt borrow from this ingenious and important art ſo much only as may throw ſome light upon the properties of the colouring matters.

20. The difficulty of diſtinguiſhing and claſſing the ſpecies of vegetable colouring matters,

matters, proceeds eſpecially from the circumſtance that we do not exactly know the nature of each of them; accordingly it is impoſſible to diſpoſe them, at leaſt in an exact and ſatisfactory manner, according to their chemical properties; it is very evident that the diviſion of Macquer can no longer be adopted. What can be done in this reſpect, reduces itſelf to the conſideration of theſe colouring matters as forming four genera hitherto very inaccurately divided, the diviſion of which muſt be a mere outline. Theſe four genera are, 1. the pure extractive colours; 2. the oxigenated extractive colours; 3. the carbonated colours; 4. the oily or reſinous hidrogenated colours.

21. We may rank the firſt genus, namely, amongſt the *pure extractive colours*, thoſe which appear in fact to be entirely ſimilar to the extractive, which are perfectly ſoluble in hot water, which do not quit this ſolvent by cooling, which cannot be applied to the ſtuffs unleſs by the help of the ſaline or metallic mordants that decompoſe them, and oxide them in ſuch a manner as to render them inſoluble. By theſe means, and by employing tartar, alum, the acids, and eſpecially the metallic oxides and ſalts, they are made to approach to the nature of thoſe of the ſecond genus, oxigen is furniſhed to them, their colour indeed is changed, they are modified in a manner which we ought to know previous to uſing them; but they are ſeparated from the water, and they are made to depoſit themſelves

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upon and attach themfelves to the ftuffs. To this genus belong the Campeachy and Brazil woods, the yellow wood, madder, weld, and the firft colour of the carthamus or baftard faffron. All thefe colouring parts diffolve in water, which they tinge more or lefs ftrongly according to their colour; when mixed with alum or muriate of tin, and precipitated afterwards by an alkali, they afford lakes.

22. I place in the fecond genus of oxigenated extractive colours, thofe which have experienced, as it appears, by the effect of vegetation, a change in their nature, depending upon the abforption of oxigen, which have therefore ceafed to be foluble in water, as they originally were, and are fufceptible only of being foftened, melted and diffeminated in this boiling liquid in fmall flakes, which are precipitated from it by cooling, and confequently depofited fpontaneoufly upon the ftuffs, adhering to them and dyeing them in a folid manner. The dyers call them *root-colours.* It is fufficient to keep the ftuffs for fome time immerfed in their bath for them to acquire a fixed colour; and this is almoft always more or lefs of a fawn colour. The root of the patience, the wood and bark of the alder, and of the oak, fumac, the hufk of the walnut, and the nut-gall, are of this kind. We may alfo refer to it almoft all the barks, the woods and the roots, from which are feparated, in the pharmaceutical art, folid extracts, that become brown

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in the air, and the decoctions of which become turbid, and afford a depofit by the contact of the atmofphere.

23. In the third genus I comprehend the colours which I call carbonated, becaufe all their properties announce that they contain a large proportion of carbon to which they owe their folidity and fixability. It is thefe upon which the modern difcoveries have began to throw the greateft light, and the nature and principal properties of which Citizen Berthollet has explained in his memoirs, as alfo in his elements of the art of dyeing. Before him, chemifts had very falfe ideas concerning them, or rather they had no accurate ideas, nor fatisfactory notions of them. They believed them to be oily or refinous matters, whereas they are really neither the one nor the other. Notwithftanding the fine analyfis of the indigo, the moft remarkable of thefe colours, which was given by Bergman, nothing exact had yet been afcertained refpecting thefe fingular matters, previous to the happy application which Citizen Berthollet made of the pneumatic doctrine to the theory of colouring matters. Thefe, which comprehend in their genus annatto, archil, indigo, and paftel or woad, are not fimply extracted by the action of water from natural vegetable fubftances which contain them ready formed; they are the product of a more or lefs profound alteration, of a more or lefs advanced decompofition, of a real combuftion effected by putrefaction, in which the hidrogen has been exhaled

exhaled more or leſs ſpeedily, and the carbon has been ſet free. They are diſſolved or diffuſed in the alkalis or alkaline matters, and ſometimes by very particular proceſſes, of which I ſhall ſay a word hereafter. They are all ſuſceptible of another order of fermentation which burns them more ſtrongly, and reduces them to the pure coaly ſtate.

24. I make a fourth genus of vegetable colouring matters, which I call *hidrogenated or reſinous* colours, becauſe they are really of this nature: they are diſtinguiſhed by their inflammability, their inſolubility in water, and their ſolubility in the oils and in alcohol. The root of alkanet gives a brilliant red colour to oils. The coloured reſins, dragon's blood, the reſin of the ivy, that of guaiacum, the gum-reſins, contain this kind of colouring principle in abundance. It is perhaps one of the moſt frequent in the vegetables, ſince there is none of them that does not give colour to oil or alcohol. But theſe colours, though holding a very remarkable place amongſt chemical facts, occupy only a very ſmall one in the art which is occupied with their extraction and application; for they are ſcarcely, if at all, employed in dyeing. The roſe itſelf, a flower ſo delicate and tranſient that it has always been taken by the poets as the ſymbol of beauty, gives a tinge to alcohol which becomes reddiſh by the action of the acids, and green by that of an alkali. It is to this order alſo that we are to refer the green colour, ſo

universally diffused amongst plants, and which is nevertheless so alterable that it can never be preserved. This colouring part is soluble in the oils and in alcohol. There are also certain vegetable colours which belong to none of the four preceding genera, as they have not their characters, and there is scarce any means of dissolving them: such is the yellow of the flowers, and especially that of the petals of the ranunculus, and of several other flowers that are equally unalterable. This general distinction of colouring matters into four genera is not sufficient for considering their species. It is necessary to treat of them under another point of view, and by descending to each of them, to consider them with relation to the different general hues with which they are decorated. Here the basis of the dyer's art must serve as our guide. Under this relation there are four very distinct genera of vegetable colouring matters; the blues, the reds, the yellows and the fawn colours, with which all possible dyes are fabricated.

26. Amongst the blue colours, the indigo, the pastel, and the turnsole, present themselves.

A. The indigo is prepared, in America and Africa, with a plant called *anil:* it is the *indigofera tinctoria* of Linnæus. When mature, it is chopped and put into a tub, where it is steeped in water, on which account the tub is called the steeping vat; it there ferments, and disengages much carbonic acid and hidrogen gas; it acquires a blue colour by the progress progrefs of the fermentation. The plant, together with its water, is drawn off into a fecond veffel called the beating vat, where it is agitated, in order to feparate the carbonic acid from it, and caufe the particles of the blue fecula to approach each other: fometimes lime-water is added to it, in order to abforb the acid more fpeedily. When the coloured fecula is well collected, and the yellow liquor cleared, the whole is poured, turbid and agitated, into a third veffel called a fettling vat, where this fecula is left to depofit itfelf, and it is drawn off while ftill foft by a cock placed towards the bottom: it is then drained in canvas bags, after which it is poured in a pafte into fquare boxes, in which it is dried in the air under fheds, to defend it from the fun.

Three principal fpecies of indigo are diftinguifhed, according to its preparation and purity; the light, or the flower indigo *(indigo-flore)* which comes from Guatimala, which floats upon water, and is of a blue colour; the *coppery indigo*, which acquires the colour of copper when it is rubbed with a hard body; and the common *indigo*, which comes from Carolina, and is much lefs pure. But in thefe three fpecies it is always the fame matter which forms the blue; it differs only by the more or lefs confiderable admixture of yellow, extraneous, and extractive matters. Even the common indigo may be purified by boiling it a long time in water. The fulphuric acid foftens and diffolves indigo, altering

altering only the mucous and extractive substances that are mixed with it. The concentrated nitric acid burns it with a beautiful purplish coloured flame, and leaves a very voluminous coal: iron is found in the residuum. More diluted nitric acid turns the indigo brown, converts it into gum-resin, and into vegetable acids, according to Hauffman, who published, in 1778, a very good memoir upon this colour.

The oxigenated muriatic acid, poured upon the solution of indigo by the sulphuric acid, destroys its colour, and changes it into a brownish yellow. Citizen Berthollet has indicated this means for judging of the quality of indigo, according to the proportions of oxigenated muriatic acid which it requires to discolour it. The indigo precipitated from its sulphuric solution, dissolves in the fixed alkalis: these give it a green colour, which at last they even destroy.

Its analysis by fire, and by the acids, shows that it contains hidrogen, azote, very little iron, and much carbon. This last principle appears to be more abundant in it than in any other vegetable substance, as it forms more than half its weight. It is to this superabundance of carbon that Citizen Berthollet attributes all the chemical properties of indigo, and its colour which approaches to black.

A part of the oxigen contained in indigo may be taken from it by the bodies that have great avidity for it, such as the green sulphate of of iron and the ſulphuret of arſenic: it then becomes green and ſoluble in the alkalis and lime; but this ſolution is decompoſed, and the indigo reſumes its blue colour and inſolubility, by the contact of the air, which reſtores to it the oxigen which it had loſt, as is ſeen in the vats of indigo which become blue at their ſurface, and in the blue which is employed in the manufacture of printed calicos. Thus its blue colour, though unalterable by the acids which only diſſolve it, is owing to a certain proportion of oxigen; when it loſes part of it, it becomes green; when it is reſtored, it paſſes again to the blue; by uniting with it a too great proportion of this principle, it is entirely burned, becomes brown or fawn-coloured, paſſing through a green colour, which proceeds from the mixture of the yellow that has been formed with the blue that is left. But this brown fawn colour of the complete combuſtion does not admit of its return any more to the beautiful blue ſtate. Hence it happens that the concentrated ſulphuric, by burning it in part, gives, when employed in dyeing, only a light or pale blue, ſuch as that which is called Saxon blue; whereas, by employing lime and different other mixtures, and eſpecially a long continued application of heat and fermentation, as in the blue vats in which woollen cloths are dyed, we obtain a rich and deep blue.

B. The *paſtel* is a blue paſte, formed by the putrefaction and reduction into a kind of compoſt

poſt of the chopped ſtalks of the *iſatis tinctoria*, or of the *iſatis Luſitanica* of Linnæus. The plant, mowed and dried quickly in the ſun, is bruiſed in a mill; it is then laid in heaps, which are ſlightly ſprinkled with ſtagnant water, and guarded againſt the ſun. The fermentation is developed in them; after a fortnight, theſe heaps are opened, they are bruiſed and mixed; round balls are then formed of them, which are dried by expoſing them to the wind and ſun. When heaped upon one another, and ſprinkled with putrified water, theſe balls become heated, exhale ammonia, dry, and are reduced into a blue which is ſold in commerce in this ſtate. It is in the departments of Gard, Aveyron, and Dordagne, that this colour is prepared in this manner. In Calvados and the Lower Seine one of an inferior quality, called woad is prepared. Aſtruc has treated the iſatis like the indigo-plant, and he ſays he has extracted from it a powder of an indigo-blue colour. Mr. Gren has deſcribed a proceſs practiſed in Germany, for changing, by fermentation, the iſatis into indigo: this proceſs, which ſucceeded, and which has ſince had the ſame ſucceſs in the experiments of Dambourney, though he was not acquainted with the German proceſs, has a great analogy with the proceſs for the real indigo. A ſtrong fermentation takes place in the ſteeping tub; much froth is formed; a blue pellicle, of a gold colour at its ſurface, preſents itſelf; the liquor is very ſubject to putrefy, and requires

requires much attention in order to prevent it. The fecula is ſeparated from it by agitation and the addition of lime; it is dried in the ſhade. It is evident that the iſatis comports itſelf like the indigo plant, and gives an analogous blue, which however is leſs delicate and rich. Frequently it is mixed with it in vats, which are called paſtel-vats, on account of this addition. Though the ſame reſearches have not been made upon the paſtel and woad as upon indigo, what has been ſeen is ſufficient to prove that theſe two colouring matters, prepared and employed in the ſame manner, are of a very ſimilar nature.

C. The ſame is not the caſe with the bad blue colour known by the name of *turnſole*, which is fabricated at Grand-Gallargues in *(ci-devant)* Languedoc, by impregnating rags with the juice of the *croton tinctorium*. Theſe rags, which are called *tourneſol* in rags, being exported into Holland, are, as it appears, diſcoloured and reduced into paſte with ſoda; of this the cakes of turnſole are formed, in which I have conſtantly found ſoda, which gives them the violet-blue colour they are known to poſſeſs, and which appear to me to be the red, tinged with blue, or rendered violet by the preſence of the alkali. This tranſient colour, which is extremely alterable, and becomes red by the contact of the weakeſt acids, as well as by many other bodies, is very different from the fecula of indigo; it ſerves only to colour common paper,

paper, and produces upon a multitude of tinges or ſtains on piece goods which are quickly deſtroyed by the air and the ſun.

27. The dyeing-reds, that is to ſay the red colouring matters which may be extracted from vegetables, and which are employed for dyeing this colour, are much more numerous than the blues properly ſo called. In this genus are reckoned madder, archil, carthamus, Brazil-wood, and Campeachy or log-wood.

A. Madder, *rubia tinctorum* of Linnæus, furniſhes by its roots, when well cleaned, dried, pounded, and ſifted, a powder of a fawn or reddiſh yellow colour, from which only a part of the colour is extracted with boiling water, but the whole with water ſharpened with alkali. It is therefore of the nature of the oxigenated extractives; it is alſo ſoluble in alcohol. The alkali gives to this dye a violet colour, the ſalts a fine red colour. It is employed only with mordants. The difference of the piece goods has much influence upon that of the dyes which are obtained from it. Dambourney, Beckmann, Wath, and Wogler, have made many intereſting experiments upon the employment of this material. Scheffer, Guhliche, Poerner, Citizens Berthollet and Chaptal have alſo examined it with attention. It is with this material that the famous red cotton of Adrianople is prepared. It is now manufactured in France of ſtill greater beauty and luſtre. It appears that madder, like the carthamus, contains two different mat-

ters,

ters, the one red and the other fawn-coloured. Its decoction affords insoluble pellicles, which deposit themselves like those which are formed on the extracts. It has the property of colouring the bones of animals to which it is given mixed with their nourishment. As whatever belongs to its properties and uses interests only the art of dyeing, and presents but few general results to the science, I shall not dilate more amply upon this subject. Some modern chemists suspect that it contains an acid.

B. Archil is a kind of violet-red paste, prepared in the Canaries and at Cape Verd with the *lichen roccella*, and in the departments of Puy-de-Dome and of Cantal, with the *lichen parellus;* the first is called *orseille d'herbe*, and the second *orseille de terre.* This last is very much inferior in quality to the first. The archil is obtained by macerating these lichens, previously dried and pulverized with urine and lime. The art of preparing it has not yet been described with accuracy, and it consists in some particular manipulations which appear to be essential. Formerly it was prepared very good at Florence: Micheli has indicated the mode of its preparation, and it is after him that Hellot reports it. Archil gives its colour to water, to the alkalis, and to alcohol. This last tincture is especially used for thermometers; its colour disappears in a vacuum, and re-appears in the air. The infusion of archil is violet; acids turn it red; alum forms in it a precipitate

precipitate of a brown-red colour; the muriate of tin a reddiſh precipitate. When applied cold to marble, this infuſion gives it a fine violet colour, which remains, according to Dufay, for ſeveral years without alteration in the air. Dyeing with the archil is performed by immerſing the ſtuffs in its ſimple infuſion. But this dye is of little durability; it ought only to be employed for heightening the tints and giving greater luſtre to other colours; the dyers, from the beauty of its colour, frequently make a fraudulent uſe of this ſubſtance; the ſolution of tin cauſes it to imitate ſcarlet, and renders it as ſolid and durable as it is capable.

C. The flower of the carthamus, or baſtard ſaffron, *cartamas tinctorius* of Linnæus, when deprived of its fawn or yellow colour by water, gives, with the aid of the alkalis, another red or very deep yellow colour. This colour may be precipitated by an acid which renders it yellow as well as the liquor. The flower muſt be well waſhed, or even prepared with water, before it is finally dried, in order to deprive it of its firſt colouring part, and to preſerve the ſecond pure. This yellow may however be employed with utility, according to Beckman, for dyeing cloths: he even aſſerts that carthamus contains more of it than the yellow wood. The red colour is extracted by the alkalis, and eſpecially by ſoda, and it is precipitated upon the ſtuffs by the acids, particularly that of the lemon; the acid of the berries of the ſervice-

tree

tree may be ſubſtituted inſtead of lemon-juice, which is very dear. It is with the red fecula of the carthamus thus extracted, and dried upon plates, that the rouge uſed by ladies is prepared, by mixing it with talc or Briançon chalk, ſcraped with the ſtalks of theve-graſs. The carthamus is cultivated in the large way in Spain, in Egypt, in the Levant, and in Thuringia. It would be a very good acquiſition for France to make. Its ſeed affords a good oil, and fattens birds; its ſtalks feed ſheep and graſs in the winter; and its flower is particularly uſeful for dyeing ſilk red, poppy, orange, cherry, roſe, and fleſh-colour.

D. Brazil wood, called alſo Fernambouc, wood of St. Martha, of Japan, of Sapan, according to the places from which it is brought, is cultivated in the Iſle de France; that of the Antilles is called *breſillet,* and is the leaſt eſteemed: this is one of the matters moſt uſed in dyeing. Its botanical name is *Cæſalpina criſta, Cæs. ſappan, Cæs. veſicaria;* theſe are the three ſpecies of trees which afford the three varieties that have been indicated: the veſicaria affords the breſillet. This wood becomes red in the air; it is of a ſaccharine taſte; the heavieſt is the beſt. Boiling water, alcohol, and ammonia, take from it all its colour; it afterwards appears black. Thoſe ſolutions give a red colour to marble, which paſſes to the violet, and becomes fixed in the chocolate-

brown

brown. The acids precipitate from its decoction, flakes of a fawn-red colour. The alkalis render it crimſon or dark violet; alum forms in it a crimſon-red precipitate, and a ſecond is obtained from it by adding alkali to the liquor. The metallic ſolutions alſo produce coloured precipitates; that of the ſuper-oxigenated muriate of tin gives one of a beautiful roſe colour. The decoction of this wood, which is called Brazil *juice* in the workſhops, is more valuable when it has been kept for ſome time than when freſh. Dyeing is performed with this juice, after having previouſly impregnated the ſtuffs with alum and with tartar. It affords bright reds, which reſiſt the effects of the air pretty well, but are leſs ſolid than the madder-colours. An acid added to the liquor, before the ſtuffs are immerſed in it, communicates to them a very ſolid fawn-yellow colour. Alumine and oxide of tin give this colour much more fixity than it naturally has. The aſtringent principle alſo augments its ſolidity. Alkalis are employed for producing violets with it, but they have very little durability. It is uſeful to pulverize this wood, becauſe much more colour can then be extracted from it, and that much more quickly and eaſily. Lakes much employed for paper-ſtaining are prepared from it with alum, ſtarch, and the alkalis, which precipitate its decoction.

E. Campeachy or log-wood, *hæmatoxytum Campechianum* of Linnæus, grows in abundance

dance in Jamaica, of which it alſo bears the name: it is likewiſe abundant in St. Cruz, Martinico, and Grenada. This wood differs from the Brazil only by the dyes which it affords: its colouring part is of the ſame nature, is rendered lighter and yellow by the acids, darker and violet by the alkalis, becomes brown and black in the air, is extremely ſoluble in water, cannot be fixed alone upon the ſtuffs, but requires the action of mordants, is rendered ſolid by the metallic ſolutions, alum and tartar: it is, like the Brazil wood, an extractive colour, ſlowly combuſtible and diſ-hidrogenated by the contact of the air. It is eſpecially employed for violet dyes, and for giving a velvet appearance and luſtre to the blacks and greys; it is uſed in the dyeing of ſilk to produce a great number of dyes, from the lilac to the dark violet, by means of the ſolution of tin. Dark coloured and conſiderably ſolid lakes are alſo prepared with its decoction.

28. Though the yellow colours are extremely abundant at the ſurface of vegetables, and though theſe eſpecially are the moſt common and moſt durable ornament of their flowers, yet the number of the plants which afford ſoluble yellows applicable to dyeing, is not ſo conſiderable as the firſt aſpect might ſeem to indicate. Thoſe particularly known in this genus are weld, yellow wood, annatto, ſaw-wort, dyer's-weed, curcuma, Venus's ſumac, French-berries (Graine d'Avignon),

d'Avignon), and quercitron: there are, however, a confiderable number of others; but it is fufficient to indicate the fpecies that are the moft employed, and the moft common.

A. Weld or woald, *refeda luteola* of Linnæus. The ftalks of this ripe plant, when dried and tied in bundles, give by decoction in water a yellow colour inclining to the brown; when diluted with water, it has a green tinge. The acids render it paler, and the alkalis darker; alum forms in it a yellowifh precipitate, and the liquor preferves a lemon colour. The folution of tin produces in it an abundant precipitate, of a light yellow colour; the liquor remains turbid, but little coloured. This fubftance is employed as a yellow dye for linen, filk, and cotton; but it will not fucceed, unlefs alum and tartar be employed as mordants. The dies vary according to the proportion of the mordants and their nature. The ufe of this colouring fubftance is called *welding*. Alkalis and lime are added to it, and madder or annatto is mixed with it, in order to obtain different orange and jonquil cafts in the dyeing of the goods called calico printing. The mordant compofed of alum and of acetite of lead is employed.

B. Yellow wood comes from a large tree of the Antilles, which grows efpecially at Tobago: it is a fpecies of mulberry, *morus tinctoria*.

It

It is yellow, with orange-coloured veins: its well-charged decoction in water is of a deep red-yellow colour, which becomes of an orange yellow. The acids precipitate from it a light fecula of a greenish-yellow colour, which the alkalis re-dissolve, giving it a reddish colour. Most of the metallic salts and alum precipitate it; the last in a yellow state and little abundant, the muriate of tin of a beautiful yellow colour, and in great abundance; the acetite of lead, abundantly of an orange-yellow; the sulphate of iron in a yellow which turns brown. This wood, reduced into splinters or chips, is employed for dyeing by keeping it in a sack in the midst of the bath: its decoction gives to the goods, without any other preparation and without mordant, a yellow with a little of a brownish cast, dull, sufficiently permanent in the air; whilst weld, also without a mordant, communicates to it a pale yellow of little stability. The mordants, alum, tartar, and the muriate of tin, fix it, and render its colour lighter; the muriate of soda and the sulphate of lime render it darker; it affords the same gradations of tinges as weld. This wood has lately become known and diffused in Europe; it is of a moderate price; it is one of the most useful ingredients in dyeing, and its colour is sufficiently solid.

C. Annatto is a dry and hard paste, brownish externally, and red internally, in lumps of about a kilogramme, covered with reed-leaves. It is prepared in America with the seeds of the *urucu*, a tree which Linnæus calls *Bixa Orellana*, which are bruifed in water, and then left to macerate and ferment. The Americans, according to Labat, prepare a finer and more folid colour from it, by crufhing and ftrongly kneading thofe feeds in their hands impregnated with oil, detaching the liniment which is thus formed, and drying it in the fun. The decoction of annatto in water has a ftrong and very diftinguifhable fmell, and a difagreeable tafte. Its colour is a yellowifh red. It diffolves better in an alkali, and its colour is then a lighter orange yellow. Alcohol alfo diffolves it very well, and it enters into thofe varnifhes that have a flight orange tinge. The alkalis precipitate its alkaline folution in an orange coloured ftate, as well as alum, which forms in it an abundant lake of a deep orange colour. The fuper-oxigenated muriate of tin produces in it a precipitate of a citron-yellow colour, which is depofited flowly. It is treated by the alkalis for the yellow dyes; but affords only a fugacious colour upon wool. It is much more ufeful and much more employed for filk, which is merely kept more or lefs immerfed in it, after it has been boiled with a fifth of its weight of foap: in this manner an aurora colour is given to it. By afterwards impregnating it with vinegar or alum, it becomes orange-coloured. It is fometimes employed cold: it is alfo ufed for cotton, which is dyed orange with it, by the aid of tartar, as a mordant.

D Saw-

D. Saw-wort, *ferratula tinctoria* of Linnæus, gives without mordant a greenifh-yellow colour of no folidity; alum fixes it, and modifies the colour into a folid and agreeable yellow. The fulphate of lime gives, according to Poerner, a darker colour; the muriate of tin enlivens it very much, according to Scheffer.

E. Dyer's broom, *genifta tinctoria* of Linnæus, a plant very common in dry and mountainous fituations, gives a yellow which is much lefs beautiful than that of weld and faw-wort; it acquires a fufficient degree of folidity by alum, tartar, and the fulphate of lime.

F. Curcuma, or *terra merita, curcuma longa* of Linnæus, contains in its root which is brought to us from the Eaft Indies, but which grows alfo in fome of the Antilles, an orange-yellow colouring part, which is very bright and beautiful, and in great abundance, but of little permanency and very fugitive. Water extracts it very eafily; even the mordants give it only an imperfect fixity. The muriates of foda and ammonia are thofe which fucceed the beft, but they give it a brown caft: it can only be employed in powder. It is ufed for communicating a brilliant golden tinge to the weld yellows, and an orange to fcarlet; but thefe fhades quickly difappear in the air. The curcuma is ufeful in chemiftry for indicating the prefence of alkaline matters which caufe it to pafs into a purplifh fawn or brown colour with great energy.

Paper is coloured with glue, mixed with a decoction of this root.

G. Venus's ſumac, *fuſtet, rhus cotinus* of Linnæus, is a wood of an orange and green colour, chatoyant, which is employed in chips for dyeing, and which gives a fine orange colour, but not ſolid. It is employed only in order to obtain orange-yellow tinges with other colouring matters, which render its own more fixed and durable. It is eſpecially combined with cochineal for obtaining jonquil, gold, and chamois colours.

H. The French-berries (*Graine d'Avignon*) are the berry of the *Rhamnus infectorious* of Linnæus; it gives a ſufficiently beautiful yellow, but of no ſolidity. It is employed only with mordants and treated like weld. A ſpecies of brilliant yellow lake is prepared with it, which is employed in painting, for paper and for wood that is to be ſtained yellow.

I. Quercitron is the bark of a yellow oak of New-England, of which Mr. Bancroft has given an account, and propoſed to ſubſtitute it inſtead of weld, eſpecially for calico-printing; it is much more rich in colour than this plant, and one part of it may ſupply the place of ten. It is merely infuſed in hot water; its yellow colour is fixed upon wool with alum and muriate of tin; the latter gives it a great degree of luſtre. The Engliſh manufacturers of printed goods prefer this bark to weld, as being more economical and permitting the grounds to be better

bleached,

bleached. Dambourney ſays that the advantages indicated by Mr. Bancroft are obtained by previouſly treating the wool with muriate of tin: it is a very good acquiſition for the art of dyeing.

29. The vegetable colouring parts that give the fawn colour to ſtuffs are extremely numerous; they are in general all the aſtringent matters: employed alone and without mordants, they depoſit their colouring part upon the goods. The principal ſpecies of this genus are the outer ſhell of the walnut, the root of the walnut, ſumac, the bark of the alder, ſanders, ſoot, and eſpecially the nut-gall. All the barks contain more or leſs of this colouring principle, of the nature of the oxigenated extractive; accordingly in the numerous experiments deſcribed by the laborious and eſtimable Dambourney, *upon the ſolid dyes of indigenous vegetables*, they were always the colours placed between the yellow and the brown, carmelites, olive, cinnamon, cheſnut colours, which he obtained, either by theſe vegetable matters employed alone, or with different mordants.

A. The outer ſhell of the walnut, or the kind of pulp which covers the kernel, is white and grows black in the air, as every one knows. This blackneſs adheres to the fingers, and cannot be removed without difficulty; if immerſed in weak oxigenated muriatic acid, it immediately becomes brown. Its filtrated decoction becomes brown in the air, and gives by evaporation inſoluble pellicles, apparently reſinous and almoſt

black;

black; this is the colouring matter altered by a flight combuftion, and almoft reduced to charcoal; alcohol precipitates the folution; the muriatic acid blackens it; the muriate of tin forms with it an abundant precipitate, of an afh-fawn colour; alum produces fcarcely any; fulphate of iron renders it almoft black. The outer fhell of the walnut has a ftrong action upon iron; it diffolves it and forms ink; its colouring part has a great difpofition to unite with wool, and gives it a nut or fawn colour, to the folidity of which the mordants add little. It is an excellent colouring matter; it affords agreeable and very folid colours; it preferves the foftnefs of the wool and requires no mordant. At the Gobelins, one of the fineft dyeing eftablifhments that exifts, the outer fhells of frefh walnuts are collected in tubs; they are covered with water, and kept for one or two years before they are ufed; and it is remarked that they then yield more colouring matter; the mordants or the metallic oxides and folutions vary its tinge.

B. The root of the walnut and efpecially its bark have prefented the fame properties to Citizen Berthollet; they give the fame colours; it is only neceffary to augment the quantity, and to employ them in chips enclofed in a fack, like all the hard bodies which may attach themfelves to the ftuffs and tear them. They have the inconvenience of frequently giving unequal colours, like all the folid matters whofe colour-

ing

ing part does not distribute itself equally in the liquor; this may be avoided by a proper management of the fire.

C. Sumac, *rhus coriaria* of Linnæus, is cultivated abundantly in Spain, in Portugal, and in the South of France, for the purposes of dyeing. Its shoots are every year cut to the root; they are dried and ground for dyeing and tanning. Its infusion, which is of a somewhat greenish fawn colour, soon becomes brown in the air; the acids turn it yellow; alum renders it turbid; the acetite of lead forms in it an abundant yellowish precipitate which becomes brown. Sumac, like the nut-gall, decomposes the nitrate of silver, and reduces its metal by the contact of light: of all the astringents it is that of which the properties approach nearest to those of the nut-gall; but its black precipitate with the solutions of iron is less abundant than that of the gall. It may be substituted in place of it by using a double proportion: it gives by itself a fawn colour inclining to a green. The acetite of alumine, a common mordant amongst the calico-printers, causes it to assume a beautiful and solid yellow; its colour is so fixed that the cloth cannot be bleached in the field; on which account it is employed only for cloths with coloured grounds, the designs and colours of which are varied by different means.

D. The bark of the alder, *betula alnus* or *alba*, gives a light fawn-coloured decoction, which soon

ſoon becomes brown and turbid by the contact of the air and the abſorption of oxigen, like all the aſtringents. Alum forms in it an abundant yellow precipitate; the muriate of tin a precipitate equally abundant and of a lighter yellow. The ferruginous ſalts convert it into ink; it diſſolves the oxide of this metal very well: it is alſo employed for the black vats in the dyeing of thread.

E. Red Sanders, the only one which is uſed in dyeing, is a ſolid, compact, heavy wood, which becomes brown by expoſure to the air: it is brought from the coaſt of Coromandel. Its fine powder gives to boiling water a fawn-brown colour, inclining to red; it diſſolves ill by itſelf, but very well with the ſkin of the walnut, ſumac, and nut-galls: its colour is ſolid, and uſefully modifies that of theſe other matters. Vogler having found that alcohol diluted with water diſſolved the colouring matter of ſanders better than water does, employed this ſolution for dyeing ſamples of wool, cotton, and linen, previouſly impregnated with ſolution of tin, waſhed and dried: they acquired a poppy red; alum cauſed them to aſſume a fine ſcarlet colour; the ſulphate of copper a light crimſon; the ſulphate of iron a deep violet. The alcoholic tincture acts cold; after it has been mixed with water it requires a ſlight ebullition.

F. Soot gives to wool a brown or fawn colour, more or leſs deep, but which is periſhable, and attaches itſelf only to its ſurface without

combining

combining with it; it hardens it, and leaves a bad ſmell; it is however employed for giving a brown tinge to ſome colours, and for obtaining certain caſts which could not be obtained with other matters but with great difficulty. What is of importance here with reſpect to the hiſtory of the vegetable colouring matters, is that it may throw ſome light upon the nature of theſe matters, and prove that the oily ſubſtance of which ſoot is in part formed, is one of the matters which approach the moſt to the nature of theſe colouring parts.

G. But none of the matters which give a fawn-coloured dye, of which we have been ſpeaking, is comparable to the nut-gall with reſpect to its influence upon colorations; it forms the firſt and the ſtrongeſt of theſe dyes. It is known that the nut-gall is an excreſcence formed upon the leaves, the petiolæ and the ſmall branches of the quercus robur, when punctured by an inſect. The beſt nut-galls are brought from the Levant; thoſe of France are not uſed. The taſte of the nut-gall is acrid, acerb and extremely aſtringent; it may be employed for tanning ſkins, though in this reſpect its operation is feeble. Its nature, properties and effects have been ſucceſſively examined by Macquer, Lewis, Monnet, the chemiſts of Dijon, Scheele, Citizens Berthollet, Deyeux, and Mr. Prouſt. It was firſt ranked at the head of the aſtringents, and its effect upon iron and its ſolutions which it blackens, was aſcribed to its aſtringent

aſtringent property, which was believed to exiſt of the ſame nature in the other acerb vegetables. Its principle which blackens iron, has been found to be ſublimed by diſtillation, to paſs into its different products, to communicate itſelf to the acids and the alkalis with which it was treated, and to ſeize immediately upon iron in the ſtate of metal. Scheele afterwards extracted from it a particular acid, which has already been examined under the name of *gallic acid.* It has ſince been found that this acid can be obtained by ſublimation, that it precipitates all the metallic ſolutions, that it approaches their oxides to the ſtate of metals, that it alſo blackens iron. Moreover Citizen Berthollet has ſhown that this acid is not the only aſtringent ſubſtance or the principle of this property; that every aſtringent acts in a peculiar manner upon the ſolutions of iron; that ſome precipitate it in a brown ſtate, others dark green, others purple or violet, and others blackiſh-blue; that the nut-gall leaves a large quantity of charcoal after its analyſis; that this ſuper-abundance of charcoal contributes much to the black coloration, by remaining alone and ſolid after the combuſtion of the hidrogen. Mr. Prouſt has ſince remarked that the aſtringent part of the nut-gall effectually blackens only the highly oxigenated or red oxide of iron; that it does not act upon the too little oxided ſalts of iron; that much is gained in the preparation of black colours by employing the red ſulphate of iron. Such are the baſes upon which the

the numerous advantages of the nut-gall in dyeing are eſtabliſhed.

We ſhall ſee, in one of the ſubſequent articles, that the nut-gall contains along with the gallic acid, beſides extractive and mucilage, a certain proportion of a particular principle called tanin, which may be ſeparated from theſe different matters diſſolved with it in a decoction of nut-galls, by the acids, the alkalis and the ſalts.

F. *Uſes.*

30. The principal uſe of the vegetable colouring matters is, as we have ſeen, to ſerve in dyeing and ſometimes in painting, after they have been extracted and prepared into ſolid matters or lakes. The art of dyeing is one of the moſt beautiful that exiſts; it is one of thoſe in which human induſtry ſhows itſelf at the higheſt degree of perfection, and the products of which imitate, if they do not ſurpaſs, thoſe of nature. As the purple of Tyre rendered that city illuſtrious in antiquity, how greatly ſuperior are the moderns in this reſpect; to all that the ancients have produced, the moſt grand and beautiful, both in the multiplicity and variety of the colours, in their ſolidity, and in the refinements and number of the proceſſes which they employ, as well as the very common uſe of all the dyed ſtuffs, which with the Romans were only the marks of the conſular or patrician dignities, or the diſtinction of the rich alone, whilſt with us nothing

nothing is more common than the moſt brilliant and moſt durable colours.

Article XX.

Of the ſeventeenth of the immediate materials of Vegetables; of the Vegetable Albumen.

1. NO author on chemiſtry has yet enumerated amongſt the principles or immediate materials of vegetables the ſubſtance which I call vegetable albumen, though for more than forty years the chemiſts, eſpecially thoſe of the ſchool of Rouelle, have found ſeveral vegetable matters, and even entire plants that had the characters of animal ſubſtances. The reader will call to mind what I have ſaid above, relative to this ſubject, concerning the extractive and glutinous principles. I have alſo ſhown in the preceding articles that moſt of the vegetable colouring ſubſtances yield ammonia by analyſis, that they contain azote, and that it is probably by this analogy of their primitive nature that they have ſo much attraction for the animal matters.

2. In order that it may be well comprehended what I underſtand by the vegetable albumen, I muſt mention that the name of albumen is particularly applied in the body of animals, to a liquid, ropy, and viſcous, of an inſipid taſte, ſoluble in cold water, concreſcible and

solidifiable by heat, abandoning the water, and separating from it in the form of flakes when it is heated, turning the syrup of violets green, soluble by the alkalis, and especially by ammonia, putrefying without passing through the acid state, affording azotic gas by the nitric acid before passing into the state of oxalic acid. If there be found in the vegetable analysis a matter which combines these properties, it is evident that it will merit and ought to bear the name of *albumen*, derived from *albumen*, white of egg, which combines them in an eminent degree.

3. The first observations which led me to suspect in 1787, and soon afterwards to determine with precision the presence of an albuminous matter in vegetables, were the phenomena that were presented to me by the defecation of the juices of the most coloured green plants. In order to defecate the juices of the cochlearia, of cress, of beccabunga, it is known that it is sufficient to plunge the bottles which contain them into hot water, between sixty and eighty degrees of Reaumur's thermometer, and even a little below this temperature. The green fecula which impairs its transparence, soon concretes and collects in small solid flakes, almost round, which float at the surface of the vegetable liquids, or deposit themselves at the bottom, and are very easily separated by mere filtration. I conceived then that this kind of defecation employed in order not to alter the juices and separate

rate from them the most volatile part which characterizes them, could depend only upon the property of being coagulated by the action of the caloric, and that as this property belongs exclusively to the albumen, it indicated, in an unequivocal manner, its presence in the antiscorbutic plants.

4. I have confirmed the first idea by direct experiments. As it was impossible to consider the feculent matter of these juices, thus coagulated by heat, as pure albumine, on account of its green colour, I endeavoured to separate the colouring part from it, in which I succeeded by the following process. Juice of young cress, filtrated cold through a piece of white paper without size, left its gross fecula upon the filtre, and passed clear, but coloured with a beautiful green: exposed to the air in a flat vessel, at a temperature of the atmosphere of 23 degrees of Reaumur, it became turbid in two hours and changed its colour; a fecula of a deep green, much finer than the first, swam like a sort of flakey powder in the midst of this juice; filtrated a second time, this fecula remained upon the paper, and the juice was now only of a very pale green colour. I then plunged it in a bath, the water of which was boiling; in a few minutes it became turbid, and there was separated from it a great quantity of small whitish clots. Another portion of the same juice, left in the air, presented to me at the end of two days, grey flakes, similar to the preceding. The sulphuric acid

acid ſeparated from a third portion of the diſcoloured juice concrete clots of the ſame matter. It is evident that Rouelle took this albumen of the juices of plants for glutinous matter.

5. Theſe flakes, whether depoſited ſpontaneouſly in the air, ſeparated by fire or by an acid, if carefully waſhed in much cold diſtilled water, preſented to me in their examination moſt of the properties of albumen in part concrete. The alkalis diſſolved them quickly and eaſily; boiling water did not attack them, and gave them greater ſolidity than they had at firſt; they gave a ſenſible green tinge to paper dyed with mallow-flowers; diſtilled, they afforded ammonia; macerated in a little water, they became inflated, ſoftened, exhaled a fetid ammoniacal ſmell, and exhibited all the ſigns of the ſtrongeſt putrefaction. It undoubtedly proceeds from this albumen that the cruciferous plants become ſo quickly altered, and diffuſe ſo infectious an odour during their corruption. A portion of this albuminous portion of the creſs, expoſed to a dry and hot air, after having been well dried by preſſure in fine paper without ſize, acquired a ſort of ductility and tranſparency analogous to that of glue: in a word, it comported itſelf abſolutely like the animal albumen, from which it differed only by its inferior tenacity and viſcoſity.

6. The juices of cabbage, of cochlearia and of beccabunga, gave by the action of heat an albuminous concretion, perfectly ſimilar to that of

of the crefs. The root of patience prefented to me a very remarkable fact relative to this principle. I wifhed to prepare the extract of patience with young and fmall roots of this plant; I found thefe roots fo much charged with juice, that I had them reduced into pulp and preffed; the expreffed juice was without colour or bitter tafte; by evaporating it, I obtained no extract, but there were feparated from it many fmall concrete and white flakes, much refembling thofe that are depofited from whey during its clarification. A part of thefe flakes was precipitated to the bottom of the liquor, another raifed itfelf in a fcum to the furface of the juice. On examining them, I found them to poffefs all the properties of albumen.

7. Another circumftance in which I have likewife difcovered the prefence of the albumen in the vegetable matters, is the analyfis of the water of the lixiviation of flour; a lixiviation by which the gluten is left pure, the amilaceous fecula is precipitated in a white powder to the bottom of the water, and a mucofo-faccharine matter diffolves in this liquid. By evaporating this water, when very clear, and without any extraneous fubftance, there are feparated from it white flakes of a concrete fubftance, which collect alfo in a white fcum at the furface of the liquor. Thefe flakes, well feparated and wafhed, prefented to me all the characters of albumen. Thus there are two animal fubftances in flour, the gluten and the albumen.

8. I have

8. I have found traces of albumen in all the green feculæ, or rather in all the vegetable juices charged with a large quantity of this fecula, and in general in all the confiderably green plants; the young woods, the annual fhoots; I have not been able to extract any from perfectly formed wood, though the ammoniacal fetidity which it exhales when it is macerated in water, indicates that it is prefent in it, but in a concrete and infoluble ftate. Neither has any vegetable acid prefented to me the flighteft trace of it, though all the juices of this nature are furcharged with gummy or gelatinous mucilage, which is fpeedily depofited from them. It may be faid that here, as in the treatment of animal matters, the albumen is diffolved and changed into gelatin by the acids.

9. Since I publifhed my firft refearches upon this fubject, Citizens Deyeux and Vauquelin have defcribed the properties which they have found in feveral of the faps of trees; and from the account and comparifon of their experiments, it is not difficult to perceive that they have found albumen in thefe liquids. It appears even that it is this portion of albumen which Citizen Deyeux took for gluten, with which it has very confiderable analogies, both in its chemical characters and in its intimate nature.

Article XXI.

Of the Eighteenth of the immediate Materials of Vegetables; of the Ligneous Matter.

1. IT is not long ſince chemiſts have begun to conſider the ligneous matter as a particular principle of vegetables; they formerly believed it to be a kind of earth, and they treated, or rather they neglected it, as ſuch in all their experiments. Thus after having exhauſted the ſolid vegetable matters by decoction in water, and by the action of alcohol, what remained untouched and inſoluble after this mode of analyſis was conſidered as an earthy ſubſtance, a *caput mortuum* which they entirely neglected. However, its combuſtible property ought to have drawn them from this notion, and induced them to examine this particular ſubſtance. Some, and I myſelf was of this opinion in the firſt periods of my inquiries, had begun to diſtinguiſh it as a body different from earth, and to compare it with the fecula; but new reſearches ſoon changed my opinion in this reſpect, and I ſhall now give an account of that which they have led me to adopt, by indicating the reſults of my experiments, which will preſent the diſtinctive properties of the ligneous ſubſtance.

2. After having exhauſted a ſolid vegetable matter, eſpecially wood, bark, or a woody root, of

of all that it contains which is ſoluble in the re-agents which act only as ſolvents, and do not alter the intimate nature of the portion not diſſolved; for example, after having boiled this matter in large quantities of water, till it paſſes off without colour or taſte, and without containing any thing, there remains a pulverulent, or fibrous, or lamellated ſubſtance, more or leſs coloured, ſufficiently ponderous, inſipid and inodorous, inſoluble, and which, on account of theſe properties, was formerly conſidered as an earth. Boiling water having no action upon this body, and being incapable either of ſoftening or diſſolving it, I have thought that it conſiderably differs from the amilaceous fecula, to which I had formerly compared it, and I have conſidered it as the vegetable ſkeleton.

3. This matter, which I call the ligneous matter, or the body, preſents properties which diſtinguiſh it from all other vegetable ſubſtances, and from all the immediate materials which are extracted from plants. When it is heated in contact with the air it becomes black without melting or ſwelling: it exhales thick fumes of an acrid, pungent and peculiar ſmell, in part ammoniacal; it leaves a coal which retains its form, and from which are extracted, after it has been reduced to aſhes, ſaline matters, eſpecially a little pot-aſh, ſulphate of pot-aſh, ſulphate of lime and phoſphate of lime. When it is diſtilled in the retort, it affords water, a particular acid known by the name

of *pyroligneous acid*, oil, in part thick, concrete and empyreumatic; carbonated hidrogen gas and carbonic acid, and a portion of ammonia combined with pyroligneous acid. The coal which remains after this diſtillation has conſtantly the form of the wood, or of the fragments of wood that have been ſubjected to diſtillation, and it comports itſelf like that which is obtained by heating the ligneous ſubſtance in contact with the air. The ammonia, one of the conſtant products of the ligneous ſubſtance, proves that this ſolid matter contains azote among its primitive principles, and I have found that it afforded about one hundredth of its weight. I have no doubt but that ſome woods may be met with which will yield more of it.

4. One of the characters which moſt eſſentially diſtinguiſh the ligneous ſubſtances conſiſts in the property which it has of yielding, by the action of fire, a particular acid, different from theſe that are obtained in the analyſis of any of the other immediate materials of vegetables, and which on that account has been called in the methodical nomenclature the *pyroligneous acid.* I have only indicated it in the ſyſtematic enumeration of the acids, and I muſt here give an account of its properties, as being the conſtant product of the action of fire upon the vegetable matter which I examine in the preſent article. Boerhaave firſt diſtinguiſhed it by the name of *acid ſpirit of wood,* and he has remarked that the hard woods, eſpecially that of Guaiacum, furniſh

furnish the most of it. Mr. Goettling has given a particular examination of it in 1779, in Crell's Chemical Annals, and the Academicians of Dijon have successfully repeated his experiments.

5. All the woods, of whatever kind they may be, yield this acid by distillation; nothing more is requisite, in order to obtain it, than to distil this body in chips in a retort of iron or stone-ware; beech, oak, or birch are especially chosen for this purpose. A reddish, very odorous, and very pungent liquor is obtained; the distillation is stopped at the moment when the oil, which would colour and alter this product, begins to pass; or else it is rectified by a second distillation with a gentle and well-managed fire; in this manner as much as one third of acid liquor is obtained from the wood. When this acid is pure, it is simply of an amber colour, without being either oily or empyreumatic; its specific gravity is to that of distilled water, as 49 to 48.

6. In the ancient methods of distilling wood, when their different products were collected and mixed, or were suffered to confound themselves together in the receivers in which they were collected, the acid spirit was separated from them by a funnel; first there passed a small quantity of heavy oil which occupied the tube of the vessel; afterwards followed the acid liquor of a more or less deep red colour; then another portion of oil which had remained at the surface.

In this manner could be feparated, by mere mechanical means, three different products in three different veffels, by receiving them feparately according to their fpecific gravity. The acid liquor thus obtained was very highly coloured and impure; it contained a portion of oil in folution, which was gradually precipitated from it in brown and heavy drops; it diffufed an acrid empyreumatic fmell, together with that peculiar to it. It may eafily be rectified by diftilling it with a lamp or fand-heat in a retort; by this means it is feparated from the empyreumatic oil which alters it; it is obtained in a liquid of an amber-yellow colour, having no longer the fetid fmell of the firft product.

7. This acid, thus rectified and purified, or obtained from its firft diftillation made with the precautions before indicated, has a lively fmell, but which is not ftrongly empyreumatic, a very acid and flightly acrid tafte; it ftrongly reddens the blue colours, and very quickly reftores the yellow colour of the curcuma when it has become purple by the action of the alkalis. When heated in a retort, it is decompofed and burned, like all the vegetable fubftances that are treated with a ftrong fire; it affords water, carbonic acid, and leaves a fmall quantity of coal in the retort. When gently heated, it is volatilized without decompofition; its volatility does not appear to be fuperior to that of water. The pyroligneous acid has a pungent and manifeftly acid fmell, which is peculiar to

it,

it, and by which it may eaſily be diſtinguiſhed from every other odorous matter.

8. Combined with the earths and alkalis, it forms particular ſalts, different from all others that are known. Mr. Goettling has employed pyrolignite of pot-aſh treated by the ſulphuric acid, in order to extract the pure pyroligneous acid. This ſalt became much heated with the ſulphuric acid; and the pyroligneous acid thus ſeparated had loſt its empyreumatic odour, and acquired an alliaceous one. Citizen Eloy Bourſier, of Clairvaux, has begun to examine the elective attractions of this acid for the earthy and alkaline baſes. Lime and barites attract it more than the alkalis. Lime ſeems to hold the firſt rank in theſe attractions; magneſia is before ammonia. This order, if well confirmed, would be ſufficient to diſtinguiſh this acid from all others. For the reſt, the alkaline and earthy pyrolignites are not yet known with ſufficient accuracy, to enable us to preſent a hiſtory of them. It appears alſo that the pyroligneous acid acts upon the metals and their oxides after the manner of the acetous acid, and that it might be employed in ſome of the arts in the ſame manner as the latter. It exerts a colouring action upon the vegetable and animal ſubſtances; it colours wood red and brown.*

9. To this diſtinguiſhing character of the ligneous matter, of furniſhing a particular acid by

* Reſpecting this acid, which has ſince been aſcertained to be the acetous, ſee the Tranſlator's Preface. N.

by diſtillation, I ſhall ſubjoin that of affording azotic gas by the operation of the nitric acid, of being converted into malic and oxalic acids, which are in part ſaturated with lime, and into acetous acid. I muſt even remark that it is one of the vegetable matters that have afforded me the moſt oxalic acid, and that I have conſequently propoſed to ſubſtitute it in the place of ſugar for preparing this artificial acid. I ſhall ſtill add that the cauſtic alkalis, with the aid of heat, ſoften, colour, and partly diſſolve and decompoſe it.

10. Thus there can remain no doubt reſpecting the particular nature of the ligneous matter. We ſee that it differs, by the totality of its properties, from all the other immediate materials of vegetables; that it has well-marked properties; that it ought to be conſidered as the ultimate product of vegetation, as a ſubſtance the moſt ſtrongly combined in its intimate compoſition, as the moſt inſoluble, the moſt unalterable, the moſt permanent of all that are formed in plants; and that in order to make its analyſis, or to aſcertain its nature, it is actually neceſſary that we ſhould employ more powerful means, and ſtronger agents, than for treating and decompoſing any of the other materials of vegetables. It alſo reſults from the knowledge that has been acquired reſpecting the ligneous ſubſtance, that it is the moſt highly carbonated principle of the vegetables; and that this is what renders it ſo difficult to be deſtroyed,

and the caufe which gives to the coal that proceeds from its femi-combuftion fo much of the organization of the wood, that we can diftinguifh both the fpecies of the wood, and the number of annual layers.

Article XXII.

Of the Nineteenth of the immediate Materials of Vegetables; of Tanin.

1. THE particular vegetable matter, which is now called *tanin*, was formerly confounded with what was defignated by the name of *aftringent fubftance, or aftringent principle.* Citizen Seguin, in his refearches upon the art of tanning fkins, firft diftinguifhed this principle from the gallic acid, which fo frequently accompanies it in vegetable fubftances. He has particnlarly characterized it by its property of uniting with animal matters, efpecially the albumen and gelatin, of feparating them from the water in which they are diffolved, of precipitating them in infoluble fawn-coloured flakes, and of forming with them an unalterable matter, which conftitutes the bafis of tanned leather.

2. Tanin is procured by lixiviating tan or bark of oak, or of feveral other vegetables, in cold water. In this manner is obtained a liquor of a dark red colour, of an acerb and acrid-tafte, which reddens the blue vegetable colours,

colours, which is very diftinguifhable as a particular principle by its property of precipitating the folutions of glue and of albumen, and all the animal liquors that contain either of thefe matters, and of thus affording the reddifh fawn-coloured precipitate of which I am about to fpeak. The tanin is alfo diftinguifhed by the ftrong fmell which it diffufes when it is diluted or diffolved in water. By evaporating its folution, it furnifhes the tanin dry, and in a kind of extract which has not loft its properties, if the liquor has not been too much heated, but is ftill foluble in water, and again acquires its ftrong fmell when diluted, and alfo combines with the animal matters, and tans them, or renders them infoluble and unalterable.

3. The tanin is found in a number of the barks of wood, of fruits, and of acerb vegetable excrefcences. It exifts in fumac, the outer fhell of the walnut; the bark and wood of the elder, of the oak, of the afh, of feveral kinds of poplars, in the nut-gall, even in the faps of fome trees, and in general in all aftringent vegetables; the Peruvian bark and the Simarouba contain a certain quantity of it. All vegetable matters that are capable of tanning fkins fhow by that circumftance that they are charged with a greater or lefs proportion of this principle. It is known that in the proceffes of tanning, the peculiar matter of the tan, or ffolved in water, and efpecially when it faturated and concentrated folution,

penetrates

penetrates the ſoftened, diſtended and inflated ſkin, combines layer by layer with the gelatinous animal matter, and forms, while it quits the water, and unites with the gelatin, a ſolid matter, of a reddiſh or fawn colour, which contracts the texture of the membranous and cellular areolæ of the cutaneous matter, ſo as to render it, if ſaturated with it, hard and brittle; that the operation is ſtopped at different periods, in order that the leather may preſerve the degree of flexibility and elaſticity which it ought to have, from the ſofteſt and moſt ductile calf-ſkins, to the ſtrong leather of which ſoles are made; and that this combination exhales for a long time the ſmell of the tanin which it contains. I ſhall treat again of this ſubject in a more detailed and explanatory manner in the hiſtory of animal matters.

4. All vegetable matters which contain tanin, more particularly the barks and the ligneous texture in which nature forms and depoſits it the moſt abundantly, contain at the ſame time ſeveral matters that are foreign to it, and from which it is neceſſary to ſeparate it, in order to have it pure, and the better to aſcertain its true properties. Mr. Prouſt, in a Memoir ſent to the Inſtitute, has given an ingenious method for obtaining this principle pure, and intereſting experiments upon its chemical characters. He has more eſpecially taken the nut-gall for the object of his reſearches. Beſides ſome portions of extractive and mucous matter, the

nut

nut-gall contains in its ligneous texture gallic acid and tanin. The gallic acid not precipitating the fuper-oxigenated muriate of tin, whilft the tanin eminently enjoys this property. Mr. Prouft has ufefully availed himfelf of it for feparating thefe two bodies, and obtaining them diftinct.

5. By pouring decoction of nut-galls into a folution of fuper-oxigenated muriate of tin, an abundant yellow precipitate was formed. The liquor being filtrated and fet to evaporate, a new portion of this precipitate was feparated from it, which the author has called *tannate* of tin, and it afterwards retained only gallic acid, muriatic acid, and a fmall quantity of oxide of tin. This liquor being put into a bottle half full, and fulphurated hidrogen gas made to pafs into it, gave a brown fulphurated oxide of tin. Expofed afterwards to the fun and the air for fome days, it loft the portion of fulphurated hidrogen gas which it had retained, and by evaporating it, Mr. Prouft obtained pure gallic acid.

6. The precipitate formed by the fuper-oxigenated muriate of tin in the decoction of nut-galls, or the tanned oxide of tin or tannate of tin, diluted with a large quantity of water immediately after it had been obtained, was decompofed by fulphurated hidrogen gas which Mr. Prouft caufed to pafs into it: fulphurated oxide of tin was precipitated, and the pure tannin remained in folution. The liquor left

left in the air, in order that it might lose the portion of sulphurated hidrogen gas which it contained, was evaporated; its colour became deeper; it diffused to a considerable distance the characteristic smell of the tanin. Its taste was very acerb, a little bitter without being disagreeable: it became turbid during its cooling, and deposited a brown powder which was dissolved again by heat; it neither putrefied nor became mouldy; it appears eminently to resist putrefaction, and it is on this account that, according to the remark of the author, the decoction of nut-galls, after having been strongly mouldy, contains only tanin in an almost pure state; evaporated to dryness, it afforded a brown, dry, friable matter, vitreous and brilliant in its fracture, resembling aloes, not deliquescent, of a very acerb taste, soluble in water, and much more so in alcohol. This is pure tanin in the dry extractive form.

7. Mr. Proust has found, since the process by the muriate of tin, another method of obtaining the pure tannin from the decoction of nut-galls. This method, which is better than the preceding, consists in precipitating this decoction by pulverized carbonate of pot-ash, in washing the greenish-grey flakes that are obtained well with cold water, and afterwards drying them in a stove. The precipitate grows brown in the air, becomes brittle and brilliant like a resin, and nevertheless remains soluble in hot water: this is very pure tanin.

8. The

8. The ſolution of purified tanin, when poured into a ſolution of glue, forms in it a magma, which may be preſſed out between the fingers, which is ſoft, ductile, and appears to ſhrink together. It may be elongated, and drawn out more than the gluten of the flour of wheat, and forms in its extenſion a fine gold-coloured membrane, which contracts as it dries, and then becomes brown and brittle, vitreous, indeſtructible, inſoluble in water and in alcohol; it reſumes its properties and characters by ſoftening in hot water: the animal albumen is precipitated by this principle like the gelatin, but it does not form an elaſtic magma. The tanned gluten may be obtained with the ſimple decoction of nut-galls poured into a ſolution of glue; but as the tanin can no more be ſeparated from it without decompoſing both of theſe matters when once united, this proceſs cannot be employed for obtaining the tanin pure and ſeparate from the gallic acid, &c.

9. The ſolutions of lead being precipitated at the ſame time by the tanin and the gallic acid, can not ſerve for ſeparating theſe two materials. The red ſulphate of iron forms with tanin, according to the chemiſt of Segovia, an abundant precipitate, which at firſt is of a dirty blue colour, and becomes black by drying. This precipitate differs much, according to him, from the gallate of iron, which is very light, remains for a long time ſuſpended, and has a black colour reſembling that of Indian ink.

Pure

Pure green ſulphate of iron is as little precipitated by tanin as by the gallic acid. The gallate of iron is eaſily and entirely ſoluble in the acids; the tanate of iron, on the contrary, is decompoſed, abandons the iron to them, and depoſits the tanin pure: all the acids alſo ſeparate the tanin from water.

10. When the red ſulphate of iron is precipitated by tanin, a portion of the latter diſoxides the iron, and cauſes it to paſs again into the ſtate of green ſulphate of iron; the oxigenated tanin remains in ſolution in the liquor: it is equally obtained by the oxigenated muriatic acid, which deepens the colour of the ſolution of tanin, and cauſes it to loſe its tanning property. Mr. Prouſt, who ſays that he does not yet know the new ſtate of this oxigenated tanin, compares this principle to the gallic acid, and finds great analogies between them. According to his experiments, the gallic acid loſes, its properties, like the firſt, more eſpecially that of precipitating the ſulphate of iron in a black ſtate. This is what he believes to take place in old inks and writings; where the gallic acid becomes oxigenated by the contact of the air. Perhaps indeed theſe two materials may differ only by a ſlight proportion of their principles, as they conſtantly accompany each other in vegetables, where they appear to be formed together, and perhaps at the expenſe of each other.

11. How-

11. However it may be with their analogy and their approximation, it is neverthelefs certain, in the prefent ftate of our knowledge, that the tanin is a vegetable matter much diffufed, efpecially in all the ligneous vegetables, almoft always attached to or combined with wood, well characterized by its fmell, its acerb tafte, its property of precipitating and hardening animal matters, of preferving them, and rendering them unalterable, its eminently antifeptic quality, its property of becoming coloured in the air, and of giving a brown and black dye. There is reafon to believe that this very remarkable vegetable principle is the common and general fource of the aftringent property; that it is the principal feat of the virtue which the phyficians call *antifeptic;* that it is perhaps the matter which cures fevers, and the periodical returns of difeafes, and that laftly all the beautiful and ftriking properties which it prefents, not only required that I fhould treat of them at length, but alfo deferve the attention of philofophers, of chemifts and of phyficians. It cannot be doubted but that this ftudy will lead to great and ufeful difcoveries.

ARTICLE XXIII.

Of the Twentieth of the immediate Materials of Vegetables; of Suber.

1. I PROPOSE to give the name of *fuber* to a vegetable matter analogous to cork, and which perfents chemical characters fimilar to thofe of that body. This matter covers all the vegetables, and forms their epidermis; it is a dry membrane, brittle, thin, femi-tranfparent, eafily rolling together by the contact of the dry air, infipid, infoluble in water, and yet feparable from the bark by the abforption of this liquid, and the inflation which it receives from it. Cork, properly fo called, feems to be only this matter more indurated, condenfed, and accumulated, fo that the epidermis of every tree, confidered under this relation, is only a layer of cork.

2. Though it was very probable, from the mere afpect and external properties of cork, which diftinguifh it fufficiently from all other vegetable matters, that it was really a fubftance different from all others, it was not till 1787 that Mr. Brugnatelli firft publifhed an obfervation that ferved to characterize cork as a particular matter. By diftilling nitric acid upon this fubftance, befides the corrofion and the yellow colour that were already known to be produced

upon it by the contact of the acid, this philosopher discovered that there was formed a particular acid different from all others before known. Citizen Bouillon La Grange has since examined this acid, which had only been announced by Brugnatelli, and has given an account of several of its properties, as well as of those of the cork itself. It was already known that cork is very light, very combustible, that it gives a white and brilliant flame; that it leaves a very light, very black, swelled coal; that it affords a little ammonia by distillation.

3. When we wish to treat this body by the nitric acid, the acid must not be taken too much concentrated nor containing too much nitrous gas, for it is susceptible of inflaming it. Carbonic acid gas and nitrous gas are disengaged during the reciprocal action of the cork and the acid. In proportion as the cork is converted into suberic acid, there is separated a yellow soft matter, which swims at the surface of this liquor, and is a particular fat matter, much resembling resin or fat: these are the yellow fragments which are seen swimming upon the nitric acid into which cork-stopper have fallen.

4. By the evaporation of the nitric acid that has acted upon cork, small needles of suberic acid of a fawn-yellow colour are separated. Citizen La Grange has employed two means for purifying it: the one consists in combining it with an alkali, evaporating the well-filtrated solution to the consistence of a syrup, afterwards precipitating

precipitating it by a ſtronger acid, ſuch as the muriatic, and waſhing it well with cold diſtilled water. The ſecond means is to boil the yellow ſuberic acid with a little water and pulverized charcoal, and to filtrate the hot liquor; the acid is depoſited by cooling, in the ſolid and cryſtalline form; it is much leſs coloured than it was at firſt: the remainder is obtained by evaporating the ſupernatant liquor. It has a harſh and acerb taſte; it reddens the blue vegetable colours; it becomes black by the contact of light; by a mild heat it is volatilized without being decompoſed; it is liquefied by the contact of oxigen gas; it diſſolves in water of which it requires at leaſt fifty parts when it is cold; hot water diſſolves much more, and it is ſeparated from it in part by cooling, in the cryſtalline form.

5. The acids with ſimple radicals do not act upon the ſuberic acid unleſs when they are concentrated, and then they burn it. Alcohol diſſolves it better than water, and aſſumes with it a ſmell of Eau de Noyau or almonds. The combinations of the ſuberic acid with the earths and the alkalis are more or leſs ſoluble; ſome of theſe ſuberates cryſtallize well, others with difficulty; there are ſome which remain in the pulverulent and inſoluble form, whilſt others are deliqueſcent. The ſtrong acids decompoſe them and precipitate from their ſolutions the ſuberic acid which ſeparates in the cryſtallized form.

 6. The

6. The ſuberic acid attacks few of the metals, if we except iron and zinc; it unites with almoſt all the oxides and forms with moſt of them inſoluble ſalts; it changes the colour of the ſalts of zinc, of iron, and of copper; it precipitates the nitric ſolutions of lead, of mercury and of ſilver in a white powder. Citizen La Grange has began to determine the elective attractions of this acid, and he has found them to be, with reſpect to the alkaline and earthy baſes, in the ſame order as thoſe of the ſulphuric, nitric and muriatic acids for theſe baſes. He has not yet been able to appreciate thoſe which it exerts upon the metallic oxides.

7. The bark of the variety of the knotty kind of elm which is called the *twiſted elm*, and which has the thickneſs, the ſoftneſs, the elaſticity and the poroſity of texture of cork, preſented to Citizen Vauquelin properties very much analogous to thoſe of cork properly ſo called, and ſome experiments made upon the epidermis of ſeveral trees have preſented to me ſufficiently marked analogies with this epidermoid ſubſtance of the oak which affords the real cork, to lead me to think that I ought to approximate all theſe matters under the generic name of *ſuber*, as forming really one of the diſtinct and conſtant materials of vegetables. It will require future labours and new reſearches to aſcertain more accurately the nature of this body, which merits all the attention of chemiſts.

8. Neither

8. Neither do I doubt but that this body, which ſo much reſembles the ligneous texture and the vegetable colouring matter, contains a certain proportion of azote amongſt its principles; and though I have yet little poſitive knowledge reſpecting its nature, at leaſt beyond what is ſufficient for diſtinguiſhing it from the other immediate materials of plants, it is however ſufficient to point out an analogy which exiſts, found between vegetables and animals, in the circumſtance that their body is ſurrounded and covered with an inſoluble texture, impervious to water, different from all the other textures of which they are formed, and really deſtined to perform a particular function in their organization.

Article XXIV.

Of the different Matters more or leſs analogous to Foſſil or Mineral Subſtances which are found mixed or combined with the immediate Materials of Vegetables.

1. IT has been ſeen by the numerous facts collected in a great number of articles of this ſeventh ſection, that all the immediate materials of vegetables are formed, in their firſt principles, of carbon, of hidrogen and of oxigen; that azote alſo enters amongſt them in ſome, which then approach

approach to the animal matters; that the fingular variety of form, of confiftence, of tafte, of fmell, of colour, and of all their chemical properties, depends almoft folely upon the different proportion of thefe primitive principles, and that it requires only a very flight variation in this proportion to give rife to a very great one in their varieties. But befides this general uniformity of compofition, which admits in the diverfity of their refpective quantities of prineiples the caufe of their diverfity of nature, there is another fource of fome differences between thefe materials, the influence of which muft here be explained, and its relations with the properties of thefe materials themfelves determined.

2. This caufe exifts in bodies foreign in fome meafure to their intimate nature, which fometimes form part of their compofition, or which vary fome of their properties, though they are only diffeminated, temporary or acceffary to them. Thefe bodies, foreign to the vegetable compofition, are foffil matters, moft frequently drawn up from the earth by the capillary tubes of the roots, and carried into the veffels of the plants with the juices or the water which thefe organs inceffantly abforb from it. They are in general of two claffes, either fimple or compound matters. I refer them; *a.* to the undecompofed combuftible bodies; *b.* to the metals; *c.* to the acids; *d.* to the earthy and alkaline bafes; *e.* to the faline fubftances; and I fhall confider them in this order.

3. Amongft

3. Amongſt the ſimple combuſtible bodies, ſulphur and phoſphorus are frequently met with in plants. Sulphur has been found in many of the cruciferous plants; their diſtilled waters, alcohol diſtilled upon theſe plants in the pharmaceutical preparations, depoſit ſulphur, even in the cryſtallized ſtate by long ſtanding. In putrefying, theſe vegetables exhale the fetid ſmell of ſulphurated hidrogen gas; the water, charged by diſtillation with what was called their *ſpiritus rector* or *aroma*, comports itſelf like a real ſolution of this gas in ſmall quantity, and depoſits ſulphur whenever this gas is decompoſed by the contact of the air and the abſorption of the oxigen. According to the experiments of Citizen Deyeux, ſulphur is extracted in powder from the fecula of the root of patience, or from this root raſped and waſhed in water, or from the ſcum which it forms when it is boiled in that liquid. Margraff has extracted phoſphorus from muſtard-ſeed heated by a ſtrong fire in diſtillation, and the phoſphoric acid of the bog-ores, and alluvial-ores, particularly of thoſe of iron is attributed to the aquatic plants under which theſe ores are formed.

4. Iron is frequently found in the ſtate of oxide in plants; it is even ſaid to have been found in metallic grains in ſtrawberries. The oxide of this metal frequently exiſts in the aſhes of vegetables. It is ſaid that thoſe of the hard woods, eſpecially of the oak, contain one twelfth of their weight of it. The colours of plants and

and that of their flowers was formerly attributed falfely to this metal. It cannot be doubted that it paffes from the interior of the earth through the roots. Scheele has found the oxide of manganefe as frequently as that of iron in vegetable afhes, and it is probable that what has frequently been taken for iron was only the oxide of this metal. Some chemifts, with Becher and Kunckel at their head, admit the prefence of gold in plants; but the very fmall quantity of this metal that can be extracted from their afhes, and which is feparated from them only by means of fufion with lead, appears to proceed rather from the latter than from the afhes themfelves, as has been proved by perfons of greater accuracy than thofe who have renewed in our days this antiquated pretenfion of chemiftry.

5. Amongft the fimple burned bodies (after water which, without being a real vegetable matter appears to be effential to the nature of plants, and neceffarily to form a conftituent part of their materials, which it dilutes and tranfports), there are only a few acids which are met with in the products of vegetables; only the carbonic acid is found pure in them; but it appears to be fo frequent and fo abundant, efpecially in the faps; that it feems to form one of the principal nutriments of plants, as I fhall fhow elfewhere. None of the other acids that are extracted from them exifts in them in a pure ftate, but always combined with earthy and alkaline

kaline bafes: fuch is the ftate of the fulphuric, nitric, muriatic, and phofphoric acids, which are united in them with pot-afh, with lime, and fometimes, though much more rarely, with foda, in faline combinations.

6. Several of the earthy and alkaline matters, of which I have given an account in the fourth fection of this work, exift alfo very frequently amongft the materials of vegetables. Silex is found in almoft all their afhes; it is fometimes in concretions, as in the *tebafheer*. Alumine exifts in them, but much lefs than has been faid. Magnefia is in the fame predicament. Lime is much more abundant in them, and is found efpecially combined with the fulphuric, phofphoric, or carbonic acids. Pot-afh is found fo frequently in them, and forms fo large and conftant a part of their burned refidues, that it was formerly confidered as belonging exclufively to plants, and on that account called *vegetable alkali*. It was even believed that it was found only in vegetables, that it was peculiar to them, and that it was formed by the very act of vegetation. Though it is well afcertained that this alkali is found amongft foffils, and that it even forms one of their principles, efpecially in the volcanic products, as I have elfewhere indicated, it is moft frequently from vegetable matters that it is extracted. After having burned herbs, and efpecially woods, their afhes are lixiviated, this lixivium is evaporated to drynefs, and in this manner the crude pot-afh or *falin* is obtained; this

falt

falt is calcined in ovens, where it is kept red-hot for feveral hours: it is in this manner that the pot-afh of commerce is prepared. It contains, befides the portion of cauftic pot-afh, which is expected, carbonate of pot-afh, fulphate of pot-afh, muriate of pot-afh, fulphate of lime, phofphate of lime, frequently oxide of iron, oxide of manganefe, filex: all thefe foreign matters are feparated by lixiviating them in very little water, by keeping this lixivium for a long time in the air, in order that the filex may be precipitated from it in proportion as the alkali abforbs the atmofpheric carbonic acid; or elfe, if it is wifhed to obtain the pot-afh pure, by treating it with alcohol, either immediately, or after having mixed it with quick lime, in order to decompofe the carbonate of pot-afh which it contains: in this manner much more of cauftic pot-afh is obtained than when the alcohol, which does not touch the falts, is employed alone and immediately in order to diffolve it.

7. Soda is much more rarely contained in vegetables than pot-afh; thofe only which grow in the water of the fea furnifh it by combuftion; and it has elfewhere been feen that it is only by the incineration of the kalis, the vareks, and the fucus, that foda is obtained upon the fea-coafts. It is moft frequently combined in plants with the muriatic acid, fometimes, though much more rarely, with the fulphuric acid. It appears, according to the analyfis of the falfola foda, made by Citizen Vauquelin,

Vauquelin, that soda exists also in the pure and caustic state in marine plants.

8. The salts, properly so called, or the saline combinations of several of the acids with simple radicals, with earthy and alkaline bases, are also met with in plants; they are even the fossil matters that are found in them the most frequently, and that are extracted from them the most easily. They are extracted from their evaporated juices; they effloresce upon their extracts; they are separated from their ashes. Such are particularly the sulphate of pot-ash, that of soda and of lime, the nitrate of pot-ash, the muriate of pot-ash, the muriate of soda, and the phosphate of lime.

9. There is reason to think that all these fossil matters, the quality of which varies incessantly amongst the vegetable products which are not necessary to their constitution, which are only accessary, and as it were accidental amongst their immediate materials, which in a word may vary greatly in their proportion and their diversity, without changing the nature itself of these materials do proceed immediately from the earth in which the roots of the plants are plunged, and that they have been absorbed by the roots of these beings with the water, which especially serves for their nourishment; accordingly they depend upon the nature of the soils in which these roots are placed.

10. Some natural philosophers have, however, thought that vegetation gave rise to them, that they

they were formed in a direct manner in the organs of the plants themselves: this opinion has especially been adopted as to pot-ash and nitre. There are some chemists who even carry this notion so far as to believe that iron is also formed by the powers of vegetable life; but far from acquiring or discovering proofs of this opinion in the facts, it appears that it becomes less and less probable in proportion to the progress which analysis makes; whilst the opinion which admits the passage of these matters from the soil itself into plants, receives every day additional confirmation.

Fifth Order of Facts, respecting the Vegetable Compounds.

Of the spontaneous Alterations of which these Compounds are susceptible.

Article I.

Of the Nature and general Causes of these Alterations.

1. ALL the phenomena, all the facts hitherto collected respecting vegetable compounds, proves, as has been shown in the preceding articles, that these compounds, being more complicated in their composition than those which belong to

to the foſſils, are alſo for the ſame reaſon much leſs permanent than the latter. The attractions which exiſt between their primitive principles, at leaſt to the number of three, permit them but rarely to remain permanent in their firſt ſtate; unleſs when their molecules being very cloſe together, and very much condenſed, do not admit between them any foreign ſubſtance, which may ſeparate them, and ſolicit thoſe of their component parts to re-act upon one another.

2. As ſoon as the circumſtance of the ſeparation of their integrant molecules takes place by the intromiſſion, either of thoſe of caloric, or of thoſe of water, which is always accompanied with the former of theſe bodies, the equilibrium of their compoſition is then ſpeedily broken, the attraction between the primitive bodies which compoſe them is changed, and aſſumes another mode; and by uniting in another manner, by tending to combine two and two, or each ſeparately, with thoſe that are moſt accommodated to them, they induce the more or leſs entire diſſolution of the firſt compound, its more or leſs profound alteration, its more or leſs complete decompoſition.

3. Such is in general the two-fold firſt cauſe of all the ſpontaneous alterations of which vegetable matters are ſuſceptible: the one reſides in the nature of their compoſition itſelf, in the weakneſs of the equilibrium which holds their principles united, in the diſpoſition which

they have to ſeparate in order to combine in another order. Nature, having intended only a tranſient and temporary adheſion in theſe vegetable compounds, has imprinted upon them the character of variability and inconſtancy: the other cauſe conſiſts in the intromiſſion of the molecules of any bodies between their own; an intromiſſion which, by weakening the connection which keeps them united, by diminiſhing their peculiar attraction, diſpoſes them to ſeparate, cauſes them to unite in another order, to form new compounds, and to appear under new forms and with new properties.

4. It is conſtantly obſerved that the effect of the inteſtine movements, which occaſion thoſe ſpontaneous changes of nature and compoſition, that the particular conſequence or the regular and determined ſeries of theſe movements, produce in general compounds leſs complicated than thoſe which have been thus ſubjected to them. Thus the hidrogen tends to unite with the oxigen and to form water; the hidrogen tends to combine with the azote, and to conſtitute ammonia; the carbon to ſeize ſeparately upon the oxigen, and to compoſe the carbonic acid. Such is alſo the conſtant termination of theſe alterations which, when conſidered under this point of view, reſemble the effect produced by the action of fire, or by that of the powerful acids, the moſt energetic oxigenated bodies.

5. But before the laſt terms of the ſpontaneous, of which theſe vegetable compounds are ſuſceptible,

ſuſceptible, is attained by the decompoſition which they undergo, they ſtop at different periods, they remain in different intermediate ſtates, they paſs through ſeveral ſucceſſive terms in which they have acquired particular characters, diſtinctive properties which may be eaſily diſcerned, and in which, by attentively watching the periods when they arrive, it is poſſible to interrupt their continuation, and to fix them in ſuch a manner as to prevent the alteration from advancing farther, or being longer continued.

6. Since obſervation has aſcertained this natural attraction of the vegetable compounds, as well as the cauſes or general circumſtances which favour it, it muſt not only throw a light upon a multitude of effects and productions which are its natural conſequences amongſt the numerous phenomena of nature, but it has has alſo led me to inveſtigate the means either of producing theſe alterations at pleaſure, or of carrying them to the point which we wiſh them to attain, or of fixing them at the period which we may find uſeful for our wants, or finally of entirely ſtopping them, and preventing them from taking place; and all the means which are at the diſpoſition of the arts are employed by man with more or leſs ſucceſs, and varied, according to the products which he may wiſh to procure.

7. The ſcience, after a long courſe of obſervations upon the ſpontaneous alterations to which the vegetables are ſubject, and which they

they experience in a manner, varied according to circumſtances, and the different agents to which they are ſubjected, has been under the neceſſity of diſtinguiſhing the nature itſelf of theſe alterations into ſeveral ſpecies. It conſiders in ſucceſſion, and in this order the fermentations, the gradual decompoſitions in the air, the ſlow and ſubterraneous action of waters, the influence of the ſoil, and the different kinds of earth upon the vegetables that are buried in it, and conſequently paſſes in review, in the courſe of theſe important conſiderations, the varied products of theſe alterations; thoſe of the fermentations, the putrefied woods, the moulds, the bitumens, the foſſil vegetables, the petrifactions, &c.

8. This manner of deſcribing and conſidering the ſpontaneous alterations of vegetable matters, which is infinitely more methodical than any that has hitherto been attempted in Elementary Treatiſes of Chemiſtry, has the advantage of preſenting, in a well-arranged ſyſtem, the totality and the ſeries of ſeveral bodies which has formerly been erroneouſly referred to the mineral kingdom. I need not remark that all theſe alterations take place only upon vegetables deprived of life, that vegetation repels them, that their effects may be conſidered as the means of natural analyſis, and that by obſerving them with much attention, the ſcience may derive great light with reſpect to the nature and compoſition of vegetable ſubſtances. This laſt point, as well as that

that of the utility of the products formed in consequence of these alterations, shall particularly occupy the subsequent articles.

Article II.

Of the Fermentations in general, and of their Distinction into several Species.

1. AS the changes which take place in vegetables by their spontaneous alterations are almost always accompanied with an intestine movement which agitates them, raises them, and seems to torment their mass, the phenomenon itself by which the vegetable matters thus subjected to the eye of the observer in the air, or in open or transparent vessels undergo these changes, has been called fermentation; so that no modification dependant upon their intimate nature, and susceptible of changing this nature itself, is said to take place without fermentation.

2. It was soon perceived in the science that this spontaneous alteration varies singularly in vegetable matters, according to the difference of their nature; and as every internal variation or change dependant upon the nature of these matters itself, and taking place without the necessary intervention of a foreign agent, has, from that circumstance alone, the character of a fermentation, it was natural for chemists

mists to distinguish the different species of fermentation.

3. Boerhaave first distinguished three fermentations, the first of which he called the *spirituous fermentation;* the second, the *acid* or the *acetous fermentation;* the third, the *putrid fermentation.* He considered them as established by nature in a constant order, and following each other regularly in that which I have just enunciated. Thus the second, according to him, could take place only after the first, and the third only after the second; whence it is easy to see that he conceived them as a series of intestine movements linked together by an equal and intimate cause, succeeding each other by an indispensable necessity, and mutually exciting each other.

4. Though several chemists have proposed some modifications of this ingenious system of Boerhaave, most natural philosophers have adopted all his notions, and this course has long been followed in the schools. That of Rouelle especially has greatly contributed to propagate, and even to extend it. Each of these fermentations was distinguished by its product. That which was called *spirituous* had for its product *spirit of wine,* or *ardent spirit,* which is now called *alcohol;* that of the second, or of the acid fermentation, was vinegar; and on this account it was called acetous, after Boerhaave; lastly, the putrid fermentation bore the name of alkaline, because the volatile alkali, or am-

monia,

monia was confidered as its effential or conftant product.

5. Some chemifts, and efpecially Bucquet, in the laft years of his life, and in his laft lectures, from 1776 to 1779, believed that this diftinction into three fpecies was not fufficient to comprehend all the alterations or fermentations of which the vegetables are fufceptible. They adduced, as proofs of their opinion, the rifing of dough, or the panary fermentation; but this manifeftly tends to form an acid, and enters into the fecond fpecies of Boerhaave: and the fermentation which develops itfelf in the colouring parts, fuch as thofe of the indigo-plant and paftel.

6. By confidering this fubject in all its extent, and under all its afpects, I have found that there are actually feveral kinds of fermentative movements, which are different from the three fermentations diftinguifhed by Boerhaave, either by their phenomena or by their product; that it was neceffary to add at leaft two very diftinct fpecies to the three admitted after the celebrated profeffor of Leyden; and that in proportion as more attentive and accurate inveftigation fhall be made into the circumftances, the conditions, and the effects of thofe fpontaneous movements which the different vegetable matters undergo, we fhall naturally be led hereafter to multiply their fpecies ftill more, and to determine their real differences.

7. I there-

7. I therefore admit five ſpecies of vegetable fermentations; the firſt is the *ſaccharine* fermentation; the ſecond, the *vinous* fermentation; the third, the *acid* fermentation; the fourth, the *colouring* fermentation; and the fifth, the *putrid* fermentation. Their diſpoſition announces that they follow each other in the order in which they have been enunciated; that there is one which precedes that which Boerhaave conſidered as the firſt, and another placed between the acid and the putrid fermentation. I ſhall here treat of them ſucceſſively in ſeparate articles; but I muſt firſt preſent a few general truths.

8. The firſt of theſe general truths is the neceſſity of well diſtinguiſhing the fermentative alteration from the other ſpontaneous changes of which the vegetables are ſuſceptible: for example from thoſe which they undergo, when, otherwiſe deprived of the conditions neceſſary to the effect of fermentation, they are immerſed in water, or buried in dry earth. Here not only the circumſtances which I may call fermentiferous are wanting, but the vegetables are themſelves ſubjected to the action of other agents capable of retarding or ſtopping their fermentation, or of acting in ſome other manner upon their compoſition. Accordingly, in the order of facts with which I am here occupied, I diſtinguiſh the formation of the ſoil, that of the bitumens and foſſilization, properly

ſo

ſo called, from the fermentations. Though the very nature of the vegetable matters, which undergo the one or the other of theſe alterations, conſiderably oppoſes any real fermentation, I ſhall ſhow, in treating of theſe phenomena, and of their products, that the extraneous circumſtances, that the inſtruments or the agents in which the vegetables are immerſed when they experience the effects very different from fermentations, modify the kind of alteration which they undergo in a very different manner.

9. A ſecond truth ſtill more nearly relating to the hiſtory of fermentation in general is, that no vegetable matter can undergo it, unleſs it be penetrated with a certain quantity of water, which, as I have already announced in the preceding article, ſeparates its particles, diminiſhes their own attraction, and diſpoſes them to act reciprocally upon one another. This neceſſity of water is ſo indiſpenſable, that the ſureſt means of preventing all fermentation conſiſts in depriving the vegetable matters completely of this liquid, by totally drying them. In the dry ſtate, theſe bodies preſerve the integrity of their compoſition; they undergo no kind of alteration or change. It is ſufficiently known, from the hiſtory of grains and ſeeds of every kind, that they are only to be preſerved ſound by keeping them in dry places, defended againſt all kind of moiſture; from

from that of plants of all kinds, of roots, ſtalks, flowers, and fruits, which are only preſerved during ſeveral ſeaſons, and even whole years, after they have been dried in the ſun or in ſtoves; and laſtly from that of the pulps, the powders, the farinæ, the extracts of all the pharmaceutical vegetable preparations, the purity and the properties of which cannot be preſerved, unleſs by reducing them to a ſtate of perfect dryneſs, and incloſing them in veſſels well defended againſt humid vapours.

10. The third truth which I muſt place here, in order to elucidate the general conditions of fermentation, and render their particular theory better underſtood, is, that a certain elevation of temperature is neceſſary to the production of this movement: no fermentation is known below the freezing point, and even moſt of thoſe movements do not begin to be excited, except at temperatures elevated above fifteen degrees of Reaumur's thermometer. Thus all fermentation is ſtopped, or rather it cannot take place under the poles, in the frozen countries and ſeaſons: and thus, on the contrary, the hotter climates preſent the fermentations in all their power, in all their activity. However, in the torrid zones, ſituated under the equator, theſe movements take place only in the more fluid vegetable matters, or in thoſe which contain much water; for thoſe which are provided only with a ſmall quantity loſe it quickly, and dry with ſuch celerity in the torrid

torrid regions, that this firft effect in general oppofes the procefs of fermentation.

11. Though thefe two circumftances, water and heat, are the two moft effential conditions of fermentation in general, their neceffity or the proportion of their influence in fome refpect varies for each fpecies of fermentation. There are fome which require only a fmall proportion of water and a temperature little elevated; others, on the contrary, require much liquid and a pretty ftrong heat. But thefe details belong to each fermentation in particular.

12. It has long been remarked that by mixing with a vegetable fubftance fufceptible of fermentation, a portion, frequently even a very fmall one, of the fame matter which has already fermented, the firft paffes into the fermentative motion with much greater celerity than if it had been alone, and paffes through it in a much more rapid manner. Every one knows that it is in this manner that the dough of wheat is made to rife more confiderably, and to ferment more quickly, by adding a fmall quantity of yeaft or of dough that has already rifen, known by the name of *leaven*. The chemifts, fince Stahl who wrote a particular work upon this fubject, have eftablifhed a theory of what were called *ferments*, which has been much abufed in medicine, into which it has been transferred. They have believed that no fermentation could be produced without the addition of an already fermented matter or a

ferment.

ferment. The phyficians, on their part, have thought that a fimilar effect took place in a multitude of difeafes, and that particularly all thofe which proceeded from a virus, efpecially the affections communicated by inoculation, by the introduction of any matter, owed their origin only to an inteftine movement occafioned by a ferment. It is at prefent well underftood, that though foreign bodies introduced between the particles of different vegetable fubftances, favour the movement of fermentation to which they are naturally difpofed, it is not neceffary that thefe bodies fhould themfelves have fermented; and that, though in the latter cafe the fermentation is generally eftablifhed in a more rapid and more evident manner, yet every extraneous fubftance capable of removing the particles afunder, and diminifhing their reciprocal adhefion, enjoys the fame property; thus the carbonic acid, by its character of eafily affuming the gafeous form, of occupying a large fpace, confequently of removing the particles of the bodies between which it is lodged, has more efpecially the property of giving rife to fermentation in them, and of developing more quickly that inteftine motion which tends to effect a change of their nature, as appears from the refearches of Mr. Henry, an Englifh chemift.

Article III.

Of the Saccharine Fermentation.

1. I TERM the faccharine fermentation an an inteftine and fpontaneous motion, which is frequently excited in feveral vegetable fubftances, and by which a faccharine matter is formed in them, which did not previoufly exift there. Since this phenomenon really exifts, and fince, without the action of any external agent or inftrument foreign to the neceffary conditions of fermentation, an infipid vegetable fubftance becomes truly faccharine, it is impoffible not to admit in this fpontaneous production an actual fermentation. The facts which I am about to collect will place this truth out of all doubt.

2. I place this fermentation in the firft rank, becaufe it really precedes the vinous fermentation which Boerhaave had confidered as the firft. In fact, we fhall foon fee that the prefence of a faccharine matter is indifpenfably neceffary to give rife to the formation of a vinous liquor; that all the mucous, infipid fubftances are abfolutely incapable of experiencing this vinous fermentation; that all thofe, on the contrary, which have a more or lefs faccharine tafte, are evidently fufceptible of it; and that the not faccharine or infipid fubftances, which fometimes

times paſs into the vinous ſtate, cannot arrive at this ſtate without previouſly contracting the taſte and all the properties of the ſaccharine matters.

3. This tranſition of the inſipid matters into the ſtate of ſaccharine ſubſtances belongs to a fermentation, and it is this which I term *ſaccharine*, becauſe its product is ſugar. I do not mean to imply that the formation of the ſaccharine matter depends always and neceſſarily upon this ſpecies of fermentation; or that becauſe a vegetable matter is ſaccharine, it has undergone this particular movement: it would be equally neceſſary to ſuppoſe that there could be no vinegar or acetous acid without the acid fermentation and the inteſtine change of a wine; whereas a multitude of chemical facts, ſeveral of which I have already preſented upon former occaſions, and to which I ſhall hereafter add ſome others, prove that acetous acid is formed by other circumſtances beſides fermentation; and we have ſeen it particularly in the action of the ſulphuric and nitric acids upon the inſipid, viſcous and dry vegetable matters. The ſame is the caſe with ſugar: ſome ſugars are formed in vegetable matters by the progreſs of vegetation itſelf; but there are ſome alſo which are produced by a kind of fermentation; and it is of this that we have to treat in the preſent article.

4. One of the firſt proceſſes in the art of brewing will be ſufficient to prove the exiſtence of the ſaccharine fermentation. It is known that barley,

barley, wheat, maize and moſt of the cereal ſeeds, penetrated firſt with a certain quantity of water, and afterwards expoſed in heaps to a temperature above 12 degrees, ſwell and announce the inteſtine movement that is excited in them by the development of the germ which ſprouts out of theſe ſeeds. At this period the brewer ſtops this motion; he heats and dries theſe germinated ſeeds by the action of the fire in the malt-kiln; and when they are well dried, he grinds them in order afterwards to prepare a decoction of them, which then is capable of fermenting and affording beer. The grain in this ſtate has acquired a ſaccharine taſte, and the water which has been boiled upon this matter has extracted from it a real ſaccharine ſubſtance which may be obtained from it by evaporation. Previous to this fermentation, it was inſipid and ſimply farinaceous, and it is a portion of this inſipid matter which has become ſaccharine by a real fermentation, and by the inteſtine motion of its own particles removed from each other by the water and the caloric; for it is impoſſible to attribute this phenomenon to any other cauſe.

5. It cannot be doubted that this ſaccharine fermentation takes place in all the cereal grains, perhaps in all the monocotyledonal ſeeds which germinate. The germination itſelf appears to be its neceſſary conſequence, or at leaſt conſtantly to accompany it. All the germinated ſeeds are in fact ſaccharine, and I have obſerved a ſufficient number of them in this ſtate, to induce

duce me to think that this phenomenon is general; it is not improbable that many of the dicotyledonal feeds prefent the fame character during their germination. Thus the faccharine fermentation, or the converfion of the mucous, infipid and feculent fubftance into fugar, by the effect of germination, may be reckoned amongft the number of the firft chemical phenomena which vegetation prefents.

6. There exift many other circumftances of the vegetable analyfis in which a faccharine matter is formed at the expenfe of another matter which was not previoufly fuch. Such efpecially is the maturation of fruits; it is univerfally known that fruits are gathered from a great number of trees when they are very far from being ripe and faccharine, that their maturation takes place only in the fruit-houfes where they are kept, and require periods of longer or fhorter duration. This obfervation is efpecially applicable to apples and pears, though it may be extended to a great number of other fruits. Thefe bodies, at the time when they are gathered from the trees, have frequently only a harfh, acerb, four and difagreeable tafte: this tafte foon experiences certain modifications; they become fweet, faccharine and agreeable; and it is too evident to require a more profound difcuffion, that in this cafe the fruits experience, in their pulp or parenchyma, an inteftine change which may be attributed to a real fermentation.

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7. The ſame modification, though not proceeding from the ſame cauſe, is remarked in ſeveral domeſtic operations. Baking in wood-aſhes or boiling in water gives many roots and fruits a ſaccharine taſte which they did not previouſly poſſeſs, and appears to develop in them this particular matter, by means of the change which the ſtrong action of the fire has produced in their principles. The caſe is the ſame with the effect produced by ſome re-agents, eſpecially by the powerful acids, in ſeveral inſipid vegetable ſubſtances, eſpecially in the germens and the amilaceous fecula. The muriatic acid gas, eſpecially the oxigenated, frequently communicates to their ſolution in water, together with a reddiſh colour and the conſiſtence of ſyrup, a ſaccharine taſte, which announces the manifeſt tranſition from the ſtate of mucous matter to that of ſaccharine ſubſtance. Laſtly, ſome modern phyſicians, Meſſrs. Rollo and Cruikſhank, think that this ſame inſipid and mucous ſubſtance is frequently converted into ſaccharine matter in the human ſtomach, when the digeſtive power or energy of its gaſtric juice are diminiſhed; they even attribute to this impaired and ſaccharine digeſtion the cauſe of a diſeaſe, which appears to be more frequent in England than in France, called the *Diabetes mellitus*, on account of the ſaccharine taſte of the urine which is diſcharged in great abundance by the patients affected with it. It is evident that in this caſe, the confirmation of which muſt be awaited

awaited from fubfequent obfervations, a real faccharine fermentation takes place in the ftomach. Something fimilar takes place in the ftomach or the mufcular glands of females that fuckle their progeny.

ARTICLE IV.

Of the Vinous Fermentation and its Products, Wine and Alcohol.

1. VINOUS fermentation is the name given to that which Boerhaave called the *fpirituous*: the latter appellation was derived from that of fpirit of wine, which was given to the product of the diftillation of wine; but this laft, being the true product of the fermentation in queftion, it is more natural and more accurate to call this fermentation *vinous*, and particularly fince the denomination of fpirit of wine which was formerly given to this liquid has been rejected. The hiftory of the vinous fermentation being one of the moft important and moft ufeful parts of vegetable chemiftry, ought to be treated with the greateft attention and in a fufficiently detailed manner to render it perfpicuous and complete. I therefore divide this article into fix paragraphs. The firft fhall treat of the definition and the literary hiftory of the vinous fermentation, the fecond of the conditions which it requires;

quires; the third of the phenomena which it prefents; the fourth of the immediate product which it yields, or of wine; the fifth of the remote or ultimate product which is obtained from it, namely alcohol; and the fixth fhall be devoted to the examinations of the caufes of the mechanifm of this fermentation and of the formation of alcohol.

SECTION I.

Definition and Literary Hiftory of the Vinous Fermentation.

2. I HAVE remarked that this fermentation is called vinous, becaufe its actual product is wine; and this is fo true that it is its confequence and neceffary effect. It ought not to be called fpirituous, not only becaufe the abfurd denomination of *fpirit of wine* has been rejected, but becaufe this is not its product or immediate production: it has not therefore been called *alcoholic* fermentation, as it ought to have been, if this firft idea of its nature and its effect had been adopted.

3. Boerhaave was the firft chemift who endeavoured to diffufe the lights of found natural philofophy over the nature of fermentation, and endeavoured to explain its caufe and phenomena. He has had the merit of renouncing the falfe

falſe theories which had been ſet up before him concerning the nature of this movement; he perceived that the ſtate of phyſics in his time was not ſufficiently advanced to afford a proper notion of its real cauſe. The defective natural philoſophy which prevailed for a long time in the ſchools in the explanation of chemical phenomena, attributed the vinous fermentation to the motion and reciprocal friction of the particles, and explained nothing by attempting to explain every thing. Becher had an idea much nearer to the truth, though ſtill far from preciſe and exact, though at leaſt ſufficiently ingenious, when he compared fermentation to a kind of combuſtion.

4. From Boerhaave to Rouelle and Macquer, nothing accurate was advanced reſpecting the vinous fermentation, but its phenomena were ſtudied and better deſcribed: the deficiencies of the hypotheſis, which till then had been maintained, were gradually perceived, and adopted with more or leſs ardour, or maintained with more or leſs zeal. Macquer, without diſcovering any thing new reſpecting the mechaniſm of this ſpontaneous commotion, collected in a more accurate manner than his predeceſſors the totality of its phenomena; he has given ſome exact experiments towards improving the fabrication and the nature of wines.

5. Many philoſophers and chemiſts have ſince laboured upon the proceſſes of the different kinds of vinification, upon the difference of

of wines, upon the art of afcertaining their quality, of correcting their defects, of obviating their depravations, of analyzing them, of improving their ufeful properties, and of feparating their alcoholic product. Amongft thefe authors we muft particularly diftinguifh Rozier, Maupin, Baumé, Bullion, to whom we owe a great number of valuable obfervations and advantageous proceffes.

6. Till the epocha of the difcovery of the decompofition and nature of water, nothing was or could be done refpecting the caufe and the mechanifm of the vinous fermentation. Since that epocha, one of the authors of this difcovery, the illuftrious Lavoifier, began by a fine courfe of experiments upon this inteftine commotion, to acquire a glimpfe of its fource; its origin and the phenomena which give rife to it. His refearches upon this part of the fcience, though ftill imperfect, as he himfelf was aware, are among the fineft monuments that have been raifed to fcience, and are to be reckoned amongft the chefs-d'oeuvre of chemiftry that have rendered this age and the French nation illuftrious.

7. It has been by the aid of the firft data of Lavoifier, both upon the formation and the decompofition of alcohol, that a feries of important difcoveries have fince been made relative to the action of this body, whether as a folvent, or a re-agent, or as acting by its intire mafs and in its perfect integrity, or as becoming altered and decompofed. Thirty years had fcarcely elapfed

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from the period when the moſt able chemiſts, Rouelle, and Macquer, conſidered, with juſtice at that time, the vinous fermentation as one of the moſt impenetrable myſteries of Nature, as a ſort of ſanctuary in which ſhe deeply concealed one of her ſecrets, till the time when the ſcience ſucceeded, almoſt all at once, in explaining this moſt myſterious phenomenon, in reſolving this intricate and difficult problem, and reducing to ſimple laws this obſcure and till then unintelligible mechaniſm.

8. Since that time a multitude of truths, which had before been myſterious, reſpecting the properties of alcohol, its lightneſs, its inflammability, its brilliant flame without ſmoke, its converſion into ether, in a word, reſpecting whatever had till then been the moſt difficult and the leaſt underſtood in chemiſtry, became ſimple facts, phenomena eaſy to be explained, the preciſe reſults of an acquired firſt truth. The diſcovery of Lavoiſier ſuddenly appeared as a pharos, which has illuminated a vaſt tract enveloped before in darkneſs, and has rendered this branch of the ſciences, though imperfect and weak before his time, much more vigorous and much more rapid in its progreſs than could have been hoped, All the details which this article will comprehend, will demonſtrate the certainty of this propoſition.

SECTION

Section II.

Conditions of the Vinous Fermentation.

9. THE conditions of the vinous fermentation are the circumftances neceffary to its formation, and without which it could not take place; when once known, nothing more is requifite than to effectuate their production and combination, in order to excite this movement; or on the other hand, to deftroy them, or prevent their taking place, in order to ftop the fermentation, to prefent an obftacle to its development. It will foon appear that one or the other of thefe circumftances is actually employed in order to modify, fuppreſs, accelerate or retard, promote or impede the vinous fermentation, and thus to give rife to more or lefs important differences in the wines.

10. The firft indifpenfable condition is the prefence of faccharine matter. All the obfervations combine to prove that this vegetable matter alone is capable of undergoing the vinous fermentation, that without it we fhould never obtain wine, and that all the vegetable liquids which contain it undergo this fermentation more or lefs eafily and powerfully. Accordingly all the juices of faccharine fruits, and efpecially the juice of the fugar cane, that of the grape,

of figs, of cherries, of plums, of apricots, of apples and of pears, paſs, when all the other circumſtances of which I am about to ſpeak are combined, into the vinous fermentation, however different in other reſpects they may be; accordingly alſo the not-ſaccharine vegetable matters become ſuſceptible of affording wine only when, by the previous ſaccharine fermentation, there has been produced in them a more or leſs conſiderable quantity of ſaccharine ſubſtance, as in barley, maize, &c. For this reaſon I have placed the ſaccharine in the firſt rank amongſt the fermentations.

11. Sugar, however, whilſt inſulated and pure, never undergoes the inteſtine movement which is to convert it into wine. Every one knows that whilſt ſolid and cryſtallized it is abſolutely unalterable, and remains in this ſtate without undergoing any kind of change. Pure ſyrup is in the ſame predicament, and though water is one of the indiſpenſable and neceſſary conditions of the production of the vinous fermentation, water and ſugar, combined with each other, never preſent the phenomena which accompany this movement, nor afford its product. This is a fact at preſent well aſcertained by exact experiments, and which reſults particularly from thoſe of the brothers Boucherie, who have made many important and accurate obſervations upon this matter in the ſugar-refinery of Bercy, near Paris.

12. The proportion of water is one of the eſſential conditions of the vinous fermentation; in order to experience it, it is neceſſary that the ſaccharine matter ſhould be diſſolved and ſufficiently liquid; too much liquid however is detrimental to it, and frequently cauſes it to paſs beyond the term of this movement, by making it paſs quickly into that which ſucceeds it; too much viſcidity is equally unfavourable to it, and prevents its taking place: accordingly when the liquid deſtined to form the wine is too thick, it is proper to add water to it; and when it is too fluid, ſugar or any ſaccharine matter which gives it a ſtronger conſiſtence is added.

13. A ſomewhat elevated temperature is alſo requiſite for the production of this movement. The vinous fermentation never eſtabliſhes itſelf below 12 degrees of Reaumur's thermometer; it begins at this temperature and proceeds rapidly at ſixteen; it is too rapid above twenty, and then requires to be conducted with caution and management in order to prevent its going beyond the production of wine. When the climate or the ſeaſon are too cold, artificial heat is applied; in the oppoſite circumſtances the fermenting matters muſt be placed in the ſhade and in low ſituations.

14. I have remarked that ſugar and water alone can never undergo the vinous fermentation; in fact, it is eſſentially neceſſary that ſome foreign matters ſhould be added to them; and this is what

what we fee in all the juices of fruits which are fubjected to it. They all contain, befides the fugar and water, mucilage, fecula, colouring matters, acids, acidules, and falts. This is the reafon why even the pharmaceutical fyrups, which fometimes contain a fmall proportion of fubftances foreign to the fugar and water, ferment; but when they are abundantly charged with them, they pafs much more quickly into this fermentation, and are more difficult to be kept. It appears that any matter, capable of dividing the faccharine liquid, is fufficient for acting as a ferment; and that it does not require to be of a particular nature, or to have already undergone the vinous fermentation in order to communicate this movement. It is on this account that, befides the well known property of all the faccharine and mixed vegetable liquors to experience the vinous fermentation fpontaneoufly, faliva, milk, and even flefh, are frequently found to be capable of exciting and accelerating this fermentation in the vegetable liquors.

15. A large mafs, a large volume, greatly favour the production and the energy of the vinous fermentation; in general, the larger the vats are in which wine is prepared, the better quality the wine is obferved to acquire; a fmall quantity of faccharine liquor never experiences, or enters only with difficulty into this kind of fermentation, whereas it paffes very quickly into the acid fermentation: we fhall foon fee upon what this difference depends.

16. The

16. The contact of the air has been confidered by almoft all chemifts as one of the indifpenfable conditions of the vinous fermentation; it ferves however only as a refervoir or recipient into which the carbonic acid which is difengaged raifes itfelf. It is not by its peculiar chemical nature that the air is of utility; it does not enter as an element into the fermenting liquor: hence this fermentation takes place in clofe veffels, provided with tubes which conduct the gas that is difengaged into a refervoir deftined for this purpofe, as has been fhown by Lavoifier. But if the matter that ought to ferment be ftrongly compreffed, if, inftead of enjoying the free contact of the air, or having a tube to ferve as a conductor for the gas, it is inclofed under covers which entirely prevent the efcape of the elaftic fluid, no fermentation, or only an imperfect fermentation takes place, becaufe there is then no gafeous extrication.

Section III.

Phenomena of the Vinous Fermentation.

17. AS foon as fermentation eftablifhes itfelf in a faccharine vegetable matter, diluted with water, mixed with one or more other fubftances, and placed under all the circumftances or conditions neceffary to its exiftence, of which we

we have juſt ſpoken, its origin, its ſtate and its termination take place in a ſeries of phenomena which not only belong peculiarly to it and characterize it, but alſo become to the obſerver certain indications of its progreſs and its modifications. It is therefore of importance that we ſhould accurately deſcribe theſe phenomena, ſince, beſides the eſtimable advantages which I have juſt announced, they may alſo guide the philoſopher in the inveſtigation of the cauſes of the vinous fermentation.

18. This fermentation commences after ſome hours or ſome days, according to the elevation of temperature to which the ſaccharine vegetable liquors are expoſed, or according to the quantity of theſe matters: it announces itſelf by a movement which agitates the liquor, which ſucceſſively diſplaces its maſſes, which tranſports in its continuity the ſolid ſubſtances, the huſks, the ſtalks, and the ſeeds, and moves them in the liquid. The fermenting liquors become heated to eighteen or twenty degrees; they become turbid; we ſee in them, when the operation is carried on in a well-lighted place, or in tranſparent veſſels, as in experiments upon a ſmall ſcale, ſtreaks of an oily appearance, which ſeem to have a tendency to ſeparate from the liquid, and to occupy its ſuperior part. We ſhould be inclined to ſay that the liquors divide themſelves into two diſtinct ſpecies, which ſeparate from each other.

19. The

19. The fermenting liquors increafe fenfibly in volume, and raife themfelves in the vats; they become covered with a fcum, fometimes very voluminous, which carries along with it all the extraneous and folid bodies: this is what is called the head in the vats in which the wine is made. This fcum is produced, as well as the rifing of the whole fermenting mafs, by the difengagement of the carbonic acid gas, which however adheres for fome time to the ftill vifcid liquor, which attaches itfelf during its difengagement to the folid matters mixed with this liquor, and raifes them along with it; which, foon becoming free, fills the upper part of the vats, and forms that atmofphere pernicious to thofe who tread the vintage without due precaution, in which Prieftley and Chaulnes firft made the interefting experiments quoted upon a former occafion, the refult of which is, that this gas is of the fame nature as that which is obtained from chalk and the alkalis by effervefcence,—which is formed by the combuftion of charcoal,—which fills the Grotto del Cano,—and which mineralizes the acidulous waters, on that account called *fpirituous waters*: in fhort, it is pure carbonic acid, carrying along with it water, and even a fmall quantity of wine in folution.

20. The quantity of carbonic acid gas difengaged in this operation is very confiderable; its difengagement commences at the moment when the vinous fermentation eftablifhes itfelf, and

and continues till the wine is entirely formed. In order that this liquor may be as ſtrong and alcoliferous as poſſible, this gas muſt be ſuffered to be entirely diſengaged: when the wine is drawn off before its complete diſengagement, ſparkling wine (*vin mouſſeux*) as it is called, and ſuch as has not undergone its complete fermention, is obtained. It is to a portion of wine in the form of vapour which this gas carries off in ſolution, eſpecially at the end of its diſengagement, that it owes the property which it poſſeſſes, of being converted into vinegar when it is diſſolved in water, according to the intereſting obſervation of Citizen Chaptal. From this gas alſo proceed the aſphixia to which perſons are expoſed who deſcend imprudently, and too deep into the vats to tread the grapes. We may aſcertain the height to which it elevates itſelf by plunging lighted tapers into the upper part of the vats; in deſcending into them the operator muſt keep his head above this height. It will be ſeen hereafter that this abundant production of carbonic acid during fermentation is one of the circumſtances from which Lavoiſier has derived the moſt light in his inveſtigation of the mechaniſm of this beautiful operation.

21. In proportion as all theſe phenomena take place, the liquor, more and more ſwelled, foaming, agitated, heated, even hiſſing in conſequence of the diſengagement of carbonic acid (on which account it is ſaid to boil), ſoon changes

changes its nature. From being mild and faccharine before, it now becomes acrid, pungent, and hot; from its former vifcid and glutinous ftate, it paffes into a very liquid and light ftate; it diminifhes in volume, it cools, its fcum difappears; the extraneous fubftances which had raifed themfelves to its furface precipitate and are depofited at the bottom; the liquor clears, and the wine is made. It is then drawn off from the vats, and put into cafks. After the wine, the carbonic acid runs off; it finks in the vat in proportion as the wine itfelf finks and yields its place to it.

22. The vinous fermentations prefent a multitude of varieties in the force, the rapidity, and the duration of the phenomena, which have juft been defcribed, according to a great number of different circumftances, in which the fermenting fubftances are fituated. The nature of the different vegetable juices, their more or lefs vifcid, thick and faccharine, or liquid and little faccharine ftate; the ripenefs of the fruit; the temperature, the place, the form of the veffels, the quantity of the liquid, the admixture of extraneous bodies in greater or lefs abundance, fuch as the ftalks, the hufks, the feeds, all produce modifications which are confidered with great attention in the art of making wine, cyder, beer, the wine of the fugar-cane, &c. A too low degree of temperature renders the fermentation languid; a too little faccharine liquor, fuch as is obtained from the unripe

unripe fruits in rainy ſeaſons, affords a weak wine, ferments badly, and frequently turns ſour. This is corrected by evaporating part of it, or by adding ſome ſugar to it, which it wants; a too viſcid liquor requires the addition of water.

SECTION IV.

Of the immediate Product of the Vinous Fermentation, or of Wine.

23. IT cannot here be expected that we ſhould give a detailed hiſtory of the art of making wines, or ſhow in all their details the differences of the varied and multiplied ſpecies of wines, deſcribe their good and bad qualities, their depravations or alterations, the means of correcting and preſerving them. Theſe objects, which are all of great importance, are not comprehended in the general theory of the ſcience: they belong to its applications. I muſt here treat of what may have a reference to them, only in a very curſory manner, and under the moſt general point of view. The knowledge of this immediate product of the vinous fermentation, and what may throw a light upon its analyſis and its compoſition, belongs alone to the elements of the ſcience. I ſhall

ſhall therefore ſpeak of wine only with reference to its general differences, its analyſis, and its uſes.

A. *Of the principal Wines.*

24. Every one knows that no product of the arts varies ſo much as wine; that every province in which the vine is cultivated has its particular wine, frequently diſtinguiſhable, and well characterized by its taſte and its ſmell; that the manner of making it contributes much to this, though in general we are more induced to attribute its differences to the ſoil and the cultivation than to the fabrication itſelf; that it would be ſuperfluous and even impoſſible to deſignate, by a particular deſcription, the innumerable varieties which this liquor preſents, even in the extent of the French Republic alone, of all the countries of the earth the moſt opulent in wines, and thoſe of the beſt kind. We can therefore here treat only of ſome generalities, and of thoſe which are the moſt important reſpecting the differences of wines from each other; and thoſe eſpecially which proceed from the different vegetables with which they are prepared, will more particularly engage our attention on account of their importance.

25. The beſt and moſt admired wines are thoſe prepared from the juice of the grape. The property which this juice poſſeſſes

of forming the beſt wines that are known, does not depend upon its containing the moſt of ſaccharine matter; for in this point of view the ſugar-cane ought to afford it, but upon its principles being united together in ſuch a manner, that there reſults from them the moſt homogeneous, the moſt uniform, and the moſt agreeable combination that can exiſt, that which is the moſt univerſally pleaſing to mankind. Wines are diſtinguiſhed into red and white: the firſt colour proceeds from the circumſtance that the wines, having ſtood in the vats for a long time, have extracted all the colouring matter of the huſks of the grape; the ſecond kind of wines are frequently prepared with coloured grapes, but the liquor is drawn off before it has acquired the tinge. Beſides the general circumſtances of the vinous fermentation already mentioned, it is to be obſerved, that each kind of grape has its own peculiar manner of fermenting; that its juice is ſeparated when we wiſh to prepare fine wine; that it is left to work in the vats for a longer or ſhorter ſpace of time before it is put into caſks; that it ſtill continues to ferment in theſe veſſels, and to aſſume the quality of perfect wine; that it is ſubject to a great number of modifications; that it depoſits tartar; that its colouring matter ſeparates by degrees, and adheres to the ſides of the veſſels, or combines with the ſugar; that it keeps more or leſs according to its ſtrength and conſiſtence; that ſometimes

ſometimes, when it is very generous, it may be kept for many years; that its quality improves by this keeping, as far as a certain term, and that afterwards it deteriorates and loſes continually, till its total decompoſition.

26. It will be of utility to give a general notion of the ſpecific differences of wines. France produces a great number that are excellent. Thoſe called Burgundy wines are the beſt for general uſe; their principles are perfectly combined, and none of them predominates; they improve greatly in quality during ſix or eight years, after which they deteriorate, but very ſlowly, and in general they keep very well. The Orleans wines, as they are called, have qualities very ſimilar to thoſe of the Burgundy wines, when time has diſſipated their tartneſs, and intimately combined their principles. The red wines of *(ci-devant)* Champagne are very delicate; the white wine, which does not ſparkle, is greatly preferable to that which does, which is not ſufficiently mature, has not ſufficiently fermented, contains little or no alcohol, and becomes flat when it has loſt its carbonic acid. The wines of *(ci-devant)* Languedoc and Guyenne, are of a deep colour, and very tonic, eſpecially when they are old. Thoſe of *(ci-devant)* Anjou are very ſpirituous, and ſoon intoxicate. The German wines, thoſe of the Rhine and the Moſelle, are white, and very full of alcohol; they keep for a long time; ſome Italian wines, thoſe

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of Orviette, of Vicenza, the *lachryma Christi*, are well fermented, and considerably resemble the good wines of France. Those of Spain and Greece are in general dry, sweet, little fermented, and unwholesome, excepting those of Rota and Alicant, which are reckoned very useful cordials. The wines of the Cape of Good Hope are perhaps the first and best of all wines.

27. Sour and harsh apples and pears contain a juice which ferments pretty well, and which affords cider and perry. When cider is left to stand upon the lees it acquires strength; when it is drawn off clear, the finest cider is formed; by adding to it fresh apple-juice sweet cider is made, which continues to ferment, and contains much carbonic acid. This liquor resembles wine in some of its properties; it differs from it, however, by its containing less tartar and much saccharine mucous substance, which is easily extracted from it by evaporation. It is on that account that when cider is distilled, without due precaution, an empyreumatic spirit of bad quality is obtained. But a cautious distillation, in which care is taken not to burn the residuum, furnishes a very good brandy, according to the experiments of Citizen Darcet. It is known that the sweet apples afford only flat cider, which is very subject to alteration.

28. Cherries also furnish, by fermentation, a species of wine from which the kind of aqua-

vitæ

vitæ known by the name of *Kirchenwaſſer* is extracted by diſtillation. Apricots, peaches, plums, alſo form wines which are not deficient in quality when they are well prepared. The juice of figs, diluted with water, likewiſe affords a very ſtrong and very generous wine, which however is not made, becauſe in the countries where figs abound they have very good vines. The juice of ſeveral ſpecies of the palm likewiſe ferments and affords a very intoxicating vinous liquor which is uſed in the Eaſt. The juice of the ſugar-cane, whilſt ſtill impure and diluted with water, undergoes a great fermentation, and affords a wine too ſtrong and too acrid to be drank in this ſtate, but it furniſhes a very ſtrong ſpirit, which in our colonies is called rum, taffia, or guildive. Thus we ſee that the number of ſaccharine vegetable ſubſtances capable of forming wine is very conſiderable; and every country may produce different wines, according to the kinds of plants which its ſoil bears and nouriſhes.

29. The ſeeds of the graminaceous plants, germinated and ſteeped in water after their fermentation, afford vinous liquors more or leſs eaſily and abundantly. Barley is principally employed for this purpoſe, though we may alſo uſe wheat, maize, and rye. Even rice affords in the Eaſt that kind of alcoholic liquor which is known by the name of arrack. The art of brewing conſiſts in the following proceſſes: The barley is ſteeped for thirty or forty hours in

water in order to foften it; this barley is laid in a heap, and fuffered to germinate; it is afterwards dried in the *touraille*, or a fquare furnace terminated by a *tremie*, upon which the germinated barley is fpread out; it is fifted in order to feparate the germs that have fprouted out of the grains, and which are called *touraillons;* it is ground into a farina called *malt;* this farina is diluted in the mefhing tun with hot water, which diffolves the faccharine mucilage: this folution is called the firft wort; it is poured again upon the malt after it has been heated, and then it forms the fecond wort; it is boiled for fome time, and put to ferment with hops and yeaft in a veffel called the fermenting back. When the fermentation has fubfided, it is agitated, or the beer is then drawn off into cafks: the fecondary fermentation, or that which fucceeds the firft, raifes from it a fcum called yeaft *(levure)*, which ferves to excite the fermentation of the decoction of barley in the *cuve guilloire.*

B. *Of the Analyfis of Wine.*

30. HOWEVER different the various fpecies of wine which I have mentioned may be, they neverthelefs all refemble each other in their general properties, and in the manner in which they comport themfelves in the analyfis to which they are fubjected. They are always liquors more or lefs coloured,

coloured, of a pungent and hot tafte, of a more or lefs aromatic odour, which revive and invigorate in fmall dofes, and in larger dofes produce that confufion, agitation, and uncertainty in the ideas and motions of animals which is called drunkennefs. They all contain a common and identical principle, from which their fimilar effects proceed.

31. In fact, all wines equally afford, by the action of fire, that acrid and inflammable liquor which is called brandy, and which differs from them only by its proportion, the facility or difficulty of its difengagement, and its particular odour which ferves to diftinguifh the kind of wine which furnifhes it. They alfo differ in the proportion of tartar, which they however all contain, or of which at leaft but very few of them are entirely deftitute; they differ alfo in the quantity and nature of the extractive colouring parts; and fome of them are more or lefs abundantly charged with mucous matter: it is this which efpecially diftinguifhes the wine of apples, of pears, of cherries, of barley, or the ciders and beers.

32. Taking true wine, or the wine of the grape, as the example, it is a compound of a large quantity of water, of a volatile and inflammable matter, very analogous in its nature to alcohol, though without being fuch, of tartar in different proportions, of an oxigenated extractive colouring matter, and of a more or lefs confiderable proportion of vegetable acids. This compound combines in all proportions with

 water,

water, though it is frequently lighter, and tends to fwim above it. It unites without decompofition with many fubftances, and efpecially with fome metals which it attacks; and with almoft all the metallic oxides, as is proved by the pharmaceutical operations by which the antimoniated or *emetic* wine, and the ferruginous or *chalybeate* wine are prepared. It diffolves many vegetable fubftances, the mucilages, the extracts, the colouring parts; it is in this manner that the medicated wines are prepared, fuch as the fcillitic, the aftringent, the antifcorbutic, the laudanum of Sydenham.

33. All the acids brighten the colour of wine, which is owing in part to the prefence of one of thefe bodies; the alkalis render it darker, and give it more or lefs of a violet caft. Alum is frequently combined with it, in order to render it more durable: the prefence of this falt is difcovered by the addition of alkalis, which feparate from it alumine of a violet colour, a kind of lake. Frequently alfo its fournefs is foftened with alkali or chalk. This bafe is difcovered in the ftate of lime in its extract when burned. The moft dangerous combination which is made with wine, in order to render it mild, and give it a faccharine tafte, is that of the oxides of lead. This liquor produces the painter's colic, or the colic of Poictou. The prefence of this metal may be afcertained by means of water charged with fulphurated hidrogen, which I firft propofed fifteen years ago, and is much preferable

to

to the alkaline ſulphurets, the effect of which is uncertain and deceptive, on account of the natural acids of the wines which precipitate them; whereas the ſulphurated hidrogen is precipitated only by the metallic oxides. We may alſo convince ourſelves of the preſence of lead in a ſtill more poſitive manner by heating the extract of the wine ſtrongly in a crucible, which produces globules of this metal. When we have to judge of a *lithargyrated* wine, as it is called, we ought not to content onrſelves with the precipitate which it forms with ſulphurated water; but we ſhould treat its reſiduum by fuſion. The preſence of copper, the green oxide of which wine alſo diſſolves very eaſily and abundantly, is demonſtrated by means of a bar of iron, which ſeparates from it the metallic copper with which this bar is ſoon covered.

34. The moſt frequent and the moſt uſeful analyſis which is performed upon wine, conſiſts in treating it by ebullition in a diſtilling apparatus. It then affords a liquid product known by the name of *brandy*. In the chemical laboratories it is diſtilled in an alembic of tinned copper, to which a receiver is adapted, and care is taken to cool the capital by keeping it continually ſurrounded with cold water. As ſoon as the wine boils in the alembic, a white, ſlightly opaque, and milky liquid, paſſes over in uninterrupted drops very cloſe to each other, of a pungent and hot taſte, of a ſtrong and pleaſant ſmell, and inflammable: this is the brandy.

brandy. The operation is continued till this product ceafes to be inflammable and pungent, and till the period when nothing more than acidulous water is condenfed. If the operation be continued, water charged with a little acetous acid is obtained. There remains in the diftilling veffel a liquor of a deep red colour, which has no longer the tafte of wine, but which, on the contrary, is acid and auftere, turbid and entirely filled with cryftals of tartar, that feparate from it. This fluid is then entirely decompofed; its original properties can no more be reftored to it; it has a four tafte. By evaporating it ftill more it is reduced to an extract of a brownifh red colour, which leaves much tartar after its difcoloration.

35. The diftillation of wine is performed upon a large fcale, in order to obtain the brandy, in the countries where this liquor, being very abundant, is at the fame time very generous or very ftrong; efpecially in feveral of the fouthern departments of the Republic, particularly in the departments belonging to what was formerly the province of Languedoc. This fine difcovery we owe to Arnaud de Villeneuve, a chemift of thofe countries, who lived in the thirteenth century. Formerly the wine was there diftilled or burned in an alembic of copper, furmounted with a long narrow cylindrical neck, terminated in a hollow hemifphere in which the vapours were condenfed: this kind of capital had a beak or a tube of little width, which received

the liquor, and conducted it into a worm. The first alteration which was made upon this apparatus was the diminution of the length of the neck; afterwards the cucurbits were made wider, though it has long been usual to contract their upper part, and to terminate it by a neck, to which was soldered, at the top, a capital in the form of an inverted cone, having at its superior part a small beak, which conducted the vapours through the worm inclosed in a tub. These machines had a great many defects by their contraction, which caused much vapour to fall back,—by the height of the cucurbit, which caused the bottom of the wine to burn,—by the construction of the furnaces which heated badly and unequally, and by the form of the capital, which repels the vapour, and causes that which is elevated to flow back.

36. According to the last method adopted by Citizen Chaptal, who has established with great sagacity some important chemical manufactures at Montpelier, we ought to employ boilers of greater width than height; their bottom is pressed inwards, in order that the fire may act equally upon all points of the liquor; they are but very little contracted at the top, and only in order to receive a wide capital surrounded with its refrigeratory; they are provided with a groove, or channel, projecting half a decimetre, and its sides inclined at an angle of seventy-five degrees, because this inclination favours the flowing down of the condensed brandy; the beak of this capital

capital is ſurrounded with a refrigeratory, from which the liquid inceſſantly runs off and remains always cool: a cock ſupercedes the neceſſity of a worm in this apparatus; and the operation produces brandy in abundance: from about one fifth to one fourth of the weight of the wine is obtained. All the modern diſtilleries are eſtabliſhed upon the ſame principles, and they afford a product of greater purity than was formerly obtained.

37. The brandy, in the proceſs that has juſt been deſcribed, is not diſengaged from the wine till the moment when the fluid boils, and at the period when it is profoundly decompoſed; it is therefore evident that it is not intirely formed or contained in it, as it requires this conſiderably elevated temperature, not only in order to diſengage it, but alſo to complete the combination of its principles. In fact, wine treated in balneo mariæ affords only a little fragrant water but no alcohol; and it is even in this manner that natural and pure wine is diſtinguiſhed from that which is artificially formed by a combination of brandy and different ingredients, or from that to which this liquor has been added in order to increaſe its ſtrength. Theſe at the heat of the balneum mariæ and without requiring to be boiled, give out the ready-formed brandy which has been added to them.

38. It is eſpecially by the different proportion of this product, called ſpirituous or alcoholic, that wines differ moſt from one another; much more is obtained from the wines of the

ſouthern

ſouthern department of the (ci-devant) Languedoc, Guyenne and Rouſſillon, than from thoſe of the central department, belonging to what were formerly called Burgundy and Champagne. The wine of the ſugar-cane or of the highly ſaccharine juices afford a great abundance of it, and it is even particularly prepared for diſtilling rum from it. A conſiderable quantity is alſo obtained from good cider and even from ſtrong beer, when diſtilled with precaution: theſe brandies are pretty good. The green and ſour wines, made in general with unripe grapes, afford only a weak brandy and in ſmall quantity. The ſparkling wines, charged with carbonic acid, the fermentation of which has been ſtopped before its completion, afford little or none. For the reſt, many experiments are ſtill wanting in order to give us a thorough knowledge of the different ſpecies of wine with reſpect to the brandy which they are able to yield, and many attempts yet to be made in order to extract it from fermenteſcible vegetables that have either not been tried at all or only in an imperfect manner.

39. Frequently only the lees, formed of tartar and extractive matter, depoſited and impregnated with vinous liquor, are diſtilled in order to extract the brandy from them. Frequently alſo only the wines that are already changed, that have begun to ſpoil, to turn ſour, and are no longer fit to be drank, are diſtilled. The lees are alſo uſed for obtaining pot-aſh: after having extracted the brandy from them by diſtillation, they

they are burned in the open air or in furnaces; the tartarous acid is decompofed; the combuftion or the incineration is carried fo far as to burn all the coal, and to reduce the afhes to the ftate of cauftic pot-afh and of carbonate of pot-afh. This fort of alkali is known in the arts by the name of pearl-afh (cendres graveleés). When analyzed with attention, we find in it, befides the cauftic pot-afh and the carbonate of pot-afh, a fmall quantity of fulphate of pot-afh, of fulphate of lime, of oxide of iron and of manganefe. Thefe four fubftances are all contained in the wines, but they vary greatly in them with refpect to their quantity. There are fome pearl-afh which contain no metallic oxides, whilft others contain only the two fulphates which I have mentioned.

40. Brandy, which is fcarcely any thing elfe than water charged with alcohol, foon ceafes to be this fimple combination, on account of the proceffes which are employed for preferving it. As foon as it is obtained it is put into cafks of frefh oak-wood; the liquid acts very fpeedily upon the wood, and diffolves an extractive, colouring and refinous matter, which gives it an amber colour, a flight tafte, and an aromatic odour, as well as a kind of confiftence fomewhat unctuous or faponaceous, and the property of forming a durable froth at its furface by agitation: this is what is called in commerce *giving a bead.* This colouring matter of the brandy grows deeper by age, and it is

by

by its intenſity as well as by that of the unctuous quality that the age of the brandy is judged of. As old brandy is in great eſtimation, it has been found very eaſy to communicate ſpeedily to it the qualities which then characterize it, by throwing into this liquor, recently prepared, chips of oak-wood, from which it quickly takes up this colouring matter and this unctuous extractive. It is likewiſe from this extraneous matter that the portion of fawn-coloured or reddiſh extract proceeds, which Dubuiſſon has obtained from the reſiduum of brandy diſtilled in large quantities.

C. *Uſes.*

41. THE uſes of wines are ſo univerſally diffuſed, that it ſeems almoſt ſuperfluous to treat of them here in particular: accordingly I ſhall ſay but little concerning them under the relation of beverage. It is ſufficiently known that theſe liquors, which to the greater part of mankind have become an article of the firſt neceſſity, ſupport the ſtrength, increaſe the tone of the fibres, and the mobility and contractile force of the muſcles; but that their abuſe, to which men are ſo much inclined, produces great evils, and at length debilitates and even totally deſtroys the powers of digeſtion; that it gives riſe to lymphatic accumulations, to obſtructions and to dropſy. This remarkable effect of drunkenneſs is particularly known, the cauſe of which has as yet

been ſo little explained, and which the liquors produce, ſometimes with extraordinary celerity. It is particularly to be obſerved that this drunkenneſs with wine is not the ſame as that occaſioned by opium, by the *tolium temulentum*, by the poiſonous plants in general, the *datura ſtramonium*, the *atropa mandragora*, *henbane*, conium *maculatitalum*, *ſolanum*, &c.

42. Wine is an excellent medicine for perſons who do not habitually make uſe of it; it is a tonic, a ſtomachic, a corroborant, a very powerful cordial. It is frequently employed as a vehicle or a recipient, for the preparation of a great number of pharmaceutical compounds. The abſurd practice of making medicinal vegetables ferment with the juice of the grape, with the intention of communicating to it the properties of thoſe plants by the fermentation itſelf, has long been laid aſide; it is now employed merely as a ſolvent, and thoſe ſpecies of wines are choſen that are beſt adapted to the nature of the qualities of the compounds which are wiſhed to be prepared with it. Wine is eſpecially and excluſively appropriated to the extraction of brandy, and this to the diſtillation of alcohol, the properties of which I am about to examine.

SECTION

SECTION V.

Of the remote Product of the Vinous Fermentation, or of Alcohol.

A. Of the means of preparing it or extracting it from Brandy.

43. I CALL alcohol the remote product of the vinous fermentation, becaufe it has been feen that it is not contained ready formed in wine, that it is obtained from it only by decompofing it by the heat of ebullition, and that it is really its remote product, or the refult of a laft analyfis. This liquor is one of the fubftances moft ufeful to fociety and to chemiftry. Previous to the eftablifhment of the pneumatic doctrine, chemifts had but a very imperfect knowledge, and erroneous ideas concerning it. Since Lavoifier we have had a much more exact knowledge of it.

44. Brandy, which, as we have feen, is obtained by diftilling wine by naked fire, is a compound of alcohol, of water and of a fmall portion of oily and extractive matter, when it has remained for fome time in cafks. In order to feparate thefe fubftances and obtain the pure alcohol, the action of fire and the procefs of diftillation are employed. There are feveral proceffes for

for obtaining the alcohol. Some chemists advise to distil the brandy in balneo mariæ a sufficient number of times to extract from it all that it contains of this matter. They recommend to separate the first quarter of the product of the first distillation, and likewise to set apart the first half of the product of the subsequent distillations, to mix together all these first products, and to rectify them by a gentle heat. The first half of the liquor which passes in this rectification is the most pure and most penetrating alcohol; the rest is alcohol of less activity, but still very good for ordinary uses.

45. Rouelle directed to extract, by distillation in balneo mariæ, the half of the brandy employed. This first product is common alcohol; by rectifying it twice in succession, and collecting only about two thirds of this first product, we obtain stronger alcohol, which is distilled again with water, according to the process of Kunckel; the water separates the alcohol from the oil which altered it; this alcohol thus distilled with the water is rectified, and we are then sure of having it perfectly pure and as highly rectified as possible. The residuum of the distilled brandy is only water charged with extractive matter and a colouring resin, covered also with a concrescible kind of oil of which I have already spoken.

46. It is easily conceived that this fluid, according to the different processes which are employed in preparing it, may have different degrees of purity. Means have long been sought for determining

determining its purity. It was at first believed that the alcohol which easily takes fire and leaves no residuum was very pure; but it is now known that the heat excited by its combustion is sufficiently strong to dissipate all the water which it may contain. The test of gun-powder has long been employed. When the alcohol lighted in a spoon upon gun-powder did not inflame it, it was considered to be bad; if on the contrary it set fire to it, it was supposed to be very good. This test however is faulty and deceptive; for when much of the best alcohol is put upon little gun-powder, the water which it furnishes in its combustion moistens the powder and it does not inflame; whereas it may be inflamed by burning upon its surface a very small quantity of alcohol charged with water. This mean was therefore not more certain than the first.

47. Boerhaave has given a very good process for ascertaining the purity of this fluid by the aid of fixed alkali. His method, if we adapt it to the present state of the science, consists in throwing into the alcohol dry pot-ash in powder. This salt unites with the superabundant water of the alcohol, and it forms, whilst it dissolves in it, a heavier and more highly coloured fluid than the alcohol, which does not mix with it but swims at the top of it. We shall see that, in the true process of Boerhaave, the pure alcohol dissolved a part of the pure pot-ash existing in the ordinary fixed alkali.

48. Several

48. Several philosophers, depending upon the circumstance that alcohol is lighter than water in a degree proportionate to its purity, have contrived instruments called areometers, by means of which we may determine with sufficient exactness the degree of purity or lightness of these fluids and of all volatile liquids. These instruments, immersed in alcohol, sink in it the deeper the more highly this fluid is rectified; they ought to be constructed in such a manner as to indicate at the same time the temperature of the liquor; otherwise they give only false notions of the weight of the alcohol. It is on this account that the areometer of Baumé is defective and not to be depended upon; that of Bories is more advantageous, since it indicates the temperature; accordingly it is that which is at present preferred by the dealers in brandy and spirituous liquors.

B. *Of the Physical Properties of Alcohol.*

49. Alcohol well prepared and well rectified is a transparent and very movable liquid, of a lively, penetrating and agreeable smell, of a hot, pungent, stimulating and acrid taste, which seems even to burn the palate and the throat. It possesses the power of intoxicating in a much more energetic degree than wine. The cause of this very remarkable property is not known.

50. It is not enough to know that alcohol is lighter than water, it is necessary that we should

determine

determine with accuracy the relation of this weight. In the moſt highly rectified alcohol, it is to that of water as 8,293 to 10,000. In that of commerce, it is as 8,371 to 10,000. In the work of Citizen Briſſon on ſpecific gravities fifteen different weights are expreſſed according to the proportions of alcohol and of water from 1 to 15; they are preſented in the following order, pure or diſtilled water being ſuppoſed 10,000.

Alcohol.	Water.	Sp. Gravity.
Parts.	Parts.	
15	1	8,527
14	2	8,674
13	3	8,815
12	4	8,974
11	5	9,075
10	6	9,199
9	7	9,317
8	8	9,427
7	9	9,519
6	10	9,598
5	11	9,674
4	12	9,733
3	13	9,791
2	14	9,852
1	15	9,919

51. Alcohol is one of the moſt volatile ſubſtances which chemiſtry poſſeſſes, and this property accords with its ſingular lightneſs. It quickly evaporates in the air, which indeed unites its ſolvent property with the expanſibility of this liquid. When we heat it even ſlightly in cloſe veſſels, it is elevated, and paſſes without alteration into the receiver: it is by this means that it is rectified and ſeparated from the ſmall quantity of water which it might contain. Accordingly the firſt portions of this diſtilled liquid are the moſt pleaſant, the moſt aromatic and the pureſt. It was formerly believed that, in the diſtillation of alcohol, there was always diſengaged a large quantity of air: it is now known that this is the moſt volatile part which ſeparates from the water and paſſes into the ſtate of gas. It boils at 64 degrees, and is in violent ebullition at 68 of Reaumur. When kept in a cloſe veſſel immerſed in water at 72 degrees of temperature, it aſſumes the gaſeous form and retains it as long as the temperature remains at that elevation.

52. It is a much better conductor of caloric than water, it is much more dilatable than the latter; on which account it is employed in the conſtruction of thermometers: it is alſo a very good conductor of electricity.

C. Of

C. *Of the Chemical Properties of Alcohol as ſolvent, and not decompoſed.*

53. In the expoſition of the numerous chemical properties of alcohol, I have found it uſeful to diſtinguiſh thoſe which it preſents in the integrity of its compoſition, or the combinations into which it enters intire; frequently as a ſolvent, ſometimes as diſſolved, from thoſe, or from the circumſtances in which it is more or leſs altered and decompoſed. Perhaps even this method might be adopted in the hiſtory of all the compound bodies. To the firſt properties belong the combinations of this inflammable liquid with the air, with ſulphur, phoſphorus, water, ſome acids, the alkalis, a conſiderable number of ſalts, and ſeveral metallic ſubſtances. I ſhall here treat of each of them in ſeparate numbers.

54. Alcohol expoſed to the air evaporates and diſſolves in it at a temperature of 10 degrees + 0; it leaves no reſiduum when it is highly rectified, and only ſome portions of water when it is leſs ſo; the more the temperature of the air is elevated, the more abundantly or ſpeedily it diſſolves in it; in proportion as this ſolution is effected, cold is produced upon the ſides of the veſſels from which the alcohol eſcapes. This may be very ſenſibly perceived by dipping the fingers in this liquid, and afterwards agitating them in the air; it is not known whether it has

more attraction for the oxigen than for the azotic gas.

55. Alcohol has no action upon solid or pulverized sulphur, neither at the common temperature, nor at that which causes it to boil. But when these two substances meet together in vapour, they unite well with each other, and there results from them a fetid sulphurated alcohol, which deposits a little sulphur, and becomes turbid in cooling, which is precipitated by water, and in which about a sixtieth part of sulphur is found; it dissolves better the sulphurated hidrogen gas which colours it a little, and which is decomposed in this combination by the contact of oxigen gas, and all the oxigenated bodies, still more quickly than when alone and in the state of gas. Alcohol takes away the sulphurated hidrogen from waters which contain it, by the aid of distillation.

56. Alcohol also dissolves a small quantity of phosphorus by heat. This fetid solution is precipitated by the contact of water; it is very luminous when it is agitated in the dark. At the moment when it is poured into water in the night, brilliant luminous tufts exhale from its surface, and there is precipitated from it an oxide of phosphorus in a white powder. Alcohol appears to be also susceptible of dissolving the phosphorated hidrogen gas.

57. Alcohol unites with water in all proportions, and is perfectly soluble in it. This solution takes place with an extrication of heat, and

and it forms kinds of factitious brandies, which are ſtronger in proportion as they contain alcohol in larger quantity. The affinity between theſe two fluids is ſo great, that water is capable of ſeparating alcohol from ſeveral ſubſtances that are united with it, and that alcohol reciprocally decompoſes moſt of the ſaline ſolutions, and precipitates the ſalts from them. It was on account of this property that Boulduc propoſed to employ alcohol for precipitating the ſalts contained in mineral waters, and for obtaining them without alteration. It is employed in a multitude of circumſtances. As the combination of alcohol and water takes place with a diſengagement of caloric, this combination is more denſe than the proportion of the two liquids indicates by the calculation of their ſpecific gravity. The alcohol is eaſily ſeparated from water by diſtillation; it paſſes firſt into vapour, and this is even, as I have already obſerved, a good means for ſeparating it from the oil which is combined with it in its ſtate of brandy.

58. Alcohol is capable of diſſolving only the weak acids, without experiencing alteration: it is in this manner that by the aid of heat, it diſſolves the boracic acid, which gives it the property of burning with a green flame. It alſo diſſolves the carbonic acid gas, which it condenſes and liquefies more than in the proportion of a volume equal to its own. It precipitates, on the contrary, the concentrated

centrated phosphoric acid, from water, in a mucous or almost concrete form, as well as those metallic acids which are soluble in the aqueous liquid.

59. No earthy bases are known that are soluble in alcohol, but the alkalis combine with it very well. Pure or caustic pot-ash and soda unite in a direct manner with alcohol, as is proved by the preparation that has long been known in pharmacy by the name of acrid tincture of tartar. In order to prepare this medicine, the pot-ash was fused in a crucible; it was pulverized whilst quite hot, it was put into a matrass; alcohol was poured to the height of three or four finger breadths above the alkali; the matrass was closed with another smaller one; they were luted together, and the whole digested in the sand-bath till the alcohol had acquired a reddish colour. There remained more or less alkali at the bottom of the vessel. All that was carbonate of pot-ash did not dissolve in it.

The too famous *lilium* of Paracelsus differed from the acrid tincture of tartar only by the circumstance that the fixed alkali, which was employed for preparing it, was reduced to the state of causticity by the strong heat to which it was subjected. Equal parts of the three alloys, then called regulus of antimony, the martial, the jovial, and that of Venus, were mixed together; they were reduced to powder, they were made to detonate with one and a half times their weight of nitre, and as much tartar; they

they were fufed, this mixture was pulverized, it was put into a matrafs, and well purified alcohol was poured upon it till it rofe three or four finger breadths above it. This mixture, put to digeft upon a fand-bath, affumed a fine red colour, deeper than that of the *acrid tincture of tartar*, and it prefented the fame phenomena. This latter might be prepared, intirely fimilar to the *lilium* of Paracelfus, by digefting the alcohol upon cauftic fixed alkali, inftead of employing fixed falt of tartar, which the action of the fire did not intirely deprive of carbonic acid, unlefs it was kept red hot for a long time.

Citizen Berthollet has afcertained that thefe tinctures are only folutions of cauftic pot-afh in alcohol, and that they afford an ufeful means of obtaining this alkali very pure, by feparating it by evaporation.

Alcohol has the fame action upon foda. By this folution we not only obtain very cauftic fixed alkalis, in a very pure ftate, (feparated from the filex, the alumine, and the neutral falts which are fo frequently united with it after treatment by lime) by rapidly evaporating their alcoholic folution in a filver veffel; but alfo by expofing to the air and to flow refrigeration their faturated folution, it yields cryftals of pot-afh and of foda in fine white plates, or in regular prifms grouped together. This is the procefs employed for obtaining thefe bafes, and the only one which gives them in the cryftalline ftate.

Ammonia combines with alcohol with an extrication of heat; it is ſeparated from it by the action of fire, as the ammonia forms a permanent gas; but it retains in gaſeous ſolution a ſmall quantity of alcohol, which modifies its ſmell and its properties.

60. Alcohol diſſolves ſeveral ſaline ſubſtances. Macquer firſt aſcertained that the ſulphates do not diſſolve in it without difficulty; that the nitrates and the muriates unite with it much better, and that in general alcohol diſſolves the ſaline ſubſtances the better in proportion as their acid has leſs adheſion with them.

Alcohol boiled upon the ſulphates of pot-aſh and of ſoda diſſolves no part of them. The carbonates of pot-aſh and of ſoda do not unite with it; theſe ſalts, inſoluble in alcohol, are even precipitated from water by this re-agent. Moſt of the ammoniacal ſalts diſſolve in alcohol. The deliqueſcent earthy ſalts eſpecially, ſuch as the calcareous and magneſian nitrates and muriates diſſolve in it abundantly. Bergman has even adviſed to employ it in order to ſeparate the deliqueſcent ſalt from the others by a firſt alcoholic lixiviation applied to the reſidues of mineral water: this proceſs may be employed to make ſome ſalts cryſtallize that are difficult to be obtained in their regular form.

A great number of metallic ſalts are alſo very ſoluble in alcohol; ſuch are eſpecially the red ſuper-oxigenated ſulphate of iron, or that in the ſtate of *mother water*, the nitrate of copper,

per, the muriates of iron and of copper, the ſuper-oxigenated muriate of mercury or *corroſive ſublimate*; all the cupreous ſalts give a very fine green colour to its flame. Since Macquer, Citizen Guyton has given, in the Journal de Phyſique, a more complete table of the degrees of ſolubility of the ſalts by alcohol.

61. Alcohol has no action upon the metallic matters, nor upon their oxides at leaſt without being decompoſed: we ſhall find hereafter that it is frequently decompoſed by the ſolutions of the metals in the acids; but this kind of action does not belong to the part of its hiſtory which we are now conſidering, and it will be retraced in that in which we ſhall have to treat of its decompoſition.

62. There are few vegetable matters upon which alcohol cannot exert a more or leſs marked action; but it is more conſiderable, according to the different nature of the immediate materials of the plants.

Margraff extracted, by means of alcohol, the ſaccharine matter of the beet-root, of ſkirret, of parſnips, &c. Since that time it has been extracted by the ſame proceſs from the ſtalks of maize, and from a great number of fruits.

The extractive matter diſſolves in it very well in general, and the better the more it is oxigenated. It conſtantly gives the alcohol a fawn or reddiſh colour.

The vegetable ſubſtances which unite the beſt with alcohol, are the volatile oils, camphor, the

the resins, the balsams, and several colouring matters.

63. The improper name of distilled spirituous water is given to alcohol, charged by distillation with a small quantity of volatile oil from the odorous vegetables: it has been thought that it united by this operation with a paricular principle of odour, which was called *spiritus rector*, or *aroma*. I shall prove that it is a small quantity of oil which it carries along with it.

In order to obtain those fluids, called *odorous spirits*, or *distilled spirituous waters*, the alcohol is distilled in *balneo mariæ* with odorous plants, or with their parts, chopped or pounded: This liquid carries off a portion of their volatile oil, and rises with it; accordingly it has the property of being precipitated and becoming white with distilled water; a portion of this oil, which renders it acrid, and at the same time very fragrant, is separated by rectifying it on the water-bath, with a very gentle heat, and taking care to draw off only three-fourths of the alcohol that has been employed, in order that we may be sure to volatilize with it only the small quantity of oil which is sufficient for giving it the odour. The small quantity which it then contains is soluble in the water that is added to it, so that no precipitation is now effected by the addition of this liquid. These fragant alcohols acquire a more

3 agreeable

agreeable fcent in proportion as they grow older, and it appears that the oily and odorous principles combine more and more intimately with the alcohol. The volatile oil has fo much attraction for alcohol, that the latter is capable of taking it away from water. In fact, when alcohol is diftilled upon water charged with the odour of a plant, the alcohol takes from it its fragrance, and leaves it entirely inodorous. A proof of this fimple theory is, that *perfumed fpirituous waters* are made by diffolving fome drops of volatile oil in alcohol, and this is the operation practifed both by the perfumers, and in the laboratories where compound liquors are prepared.

64. We may charge alcohol with a much greater quantity of volatile oil by diftillation; it then, befides the odour, acquires an acrid and burning tafte; water poured into it precipitates the oil from it abundantly in white and opaque globules; but there remains, after this precipitation, the portion which the water can diffolve, fo that the liquor always retains a ftrong odour. In general, the fmall quantity of volatile oil, which is fufficient for rendering alcohol odorous, adheres to it with great force, and it cannot be deprived of it by any known procefs.

65. Alcohol eafily diffolves camphor in the cold; but it diffolves a larger quantity when affifted by heat. This folution, when well charged, as with a quarter of its weight of

of camphor, mixed with water that is added to it by degrees and drop by drop, affords a cryſtalline vegetation, obſerved by Romieu; it is a perpendicular filament upon which are implanted needles that elevate themſelves againſt the filament, at an angle of 60 degrees. This experiment ſucceeds but very rarely, and requires great nicety with reſpect to the quantity of water, the refrigeration that is neceſſary, &c. Camphorated alcohol, united with a large quantity of water, depoſits the camphor in white concrete flakes, very pure and without alteration.

66. All the reſins are ſoluble by alcohol, but much leſs eaſily and abundantly than the volatile oils. Theſe reſinous ſolutions are thick, more or leſs tinged with a yellow, red or brown colour. Water decompoſes them immediately, and precipitates the reſins from them in fine white, opaque or ſlightly coloured globules.

The balſams diſſolve in alcohol like the reſins; when they are precipitated from it by water, their benzoic acid remains in ſolution, and only their reſinous part is depoſited.

The gum-reſins are only partially ſoluble in alcohol; and chemiſts have analyzed them by applying to them ſucceſſively this liquid and water.

Several colouring parts, not only the reſinous as has long been imagined, but alſo the oxigenated extractives, unite with alcohol, and colour it more or leſs ſtrongly: we may alſo ſeparate them from it by water, but frequently they remain united,

at

at leaft in part, with the mixture of thefe two liquids.

67. The names of *tinctures*, *elixirs*, *balfams*, *quinteffences*, &c. have been given to the compounds of oily or refinous juices and alcohol, when this is fufficiently charged with thefe fubftances to have a high colour and to be abundantly precipitated by water. Thefe pharmaceutical preparations are, like the odorous aromatic alcohols, either fimple when they contain only one matter in folution, or compound when they contain feveral at the fame time. Thefe medicines are in general prepared by expofing the juice in the ftate of powder, or the dried plant, the volatile oil of which is to be diffolved, the refin, the balfam, or the colouring extract, to the action of the alcohol, which is aided by agitation and by the mild heat of the fun, or of a fand bath. When it is wifhed to extract the refins of feveral plants or any kinds of vegetable fubftances at the fame time, care is taken firft to digeft the matter that is the leaft fubject to be attacked by the alcohol, and to expofe fucceffively to its action the fubftances that are the moft foluble in it. When this folvent is as much charged as it can be, it is filtrated through paper; fometimes a compound tincture is made immediately, by mixing feveral fimple tinctures together; in this manner the *Elixir Proprietatis* is prepared, by combining the tinctures of myrrh, of faffron and of aloes. We may feparate the refins and the balfams from the alcohol

cohol by pouring water into the tinctures or by diſtilling them; but in theſe two caſes the alcohol retains a portion of volatile oil which has been called the aromatic principle of theſe ſubſtances. Water is not capable of decompoſing the tinctures formed with what were called the extracto-reſinous or the reſino-extractives; that is to ſay, the highly oxigenated extractives, as we find in rhubarb, ſaffron, opium, gum-ammonia, &c. as theſe matters are equally ſoluble in theſe two liquids.

D. *Of the Chemical Properties which Alcohol preſents whilſt it becomes decompoſed.*

68. In a great number of chemical operations which are performed with alcohol, it comports itſelf in a very different manner from what has juſt been ſaid; it does not enter intire into the combinations: on the contrary, it is decompoſed or modified more or leſs completely, ſo far as to be reduced into its conſtituent elements ſeparated from each other: it is of this then I am now about to treat. I refer the chemical properties which produce different degrees of decompoſition in alcohol, to its treatment by a high temperature, its inflammation, its alteration by the acids, by the oxides or by the metallic ſolutions: the examination of the phenomena which it preſents in each of theſe circumſtances, conſtitutes one of the moſt important parts of modern chemiſtry.

69. When

69. When alcohol is paffed through a red-hot tube of porcelain, it is decompofed; water is obtained at the extremity, and the veffel which receives its vapours has a burned or empyreumatic odour; there is alfo difengaged a certain quantity of carbonated hidrogen gas and of carbonic acid gas. Some chemifts affure us that in this operation an ethereal product is obtained, and in fact we can at leaft perceive a fragrant odour analogous to that of ether. There are alfo conftantly depofited upon the fides of the ball, fmall white and brilliant cryftals, which refemble benzoic acid, but which have been afcertained by Citizen Vauquelin to be a kind of concrete volatile oil. The tube of porcelain, broken after the operation, prefents a very fine black foot upon its fides. This operation, which is very remarkable, has not yet been performed with fufficient care to enable us to defcribe all its circumftances with accuracy and to determine its caufe with precifion. All that we fee in a pofitive manner is that there is formed water and a little carbonic acid, that carbonated hidrogen gas is feparated, and carbon is depofited. By inveftigating with accuracy the nature and the proportion of thefe products of the incandefcence of alcohol, a refult will be obtained, of utility towards determining the nature and relative quantity of its primitive principles.

70. Alcohol has long been known to be a very inflammable fubftance: when heated in contact with the air, and efpecially when brought into con-

tact

tact with a body in the ftate of combuftion, with out being itfelf heated, or if ftruck by a ftrong electric fpark, it takes fire and burns with a very extenfive flame, which is very light, white in the middle, blue at its fides, with a pretty ftrong heat and without leaving any refiduum. Chemifts have long fince remarked that it affords in its combuftion neither foot nor fmoke. Boerhaave, by prefenting a cold veffel of porcelain to its flame had collected pure water, without tafte or fmell, and in every refpect fimilar to diftilled water; he had even concluded from this phenomenon that flame is owing to water in the ftate of vapour.

Lavoifier, by burning alcohol in a lamp placed under a receiver filled with atmofpherical air, and communicating with another receiver filled with oxigen gas, fo that this fupplied the former with the oxigen requifite for the combuftion, obtained from fixteen parts of alcohol thus burned, eighteen parts of water and of carbonic acid. Citizen Berthollet has alfo remarked that when alcohol mixed with water was burned, the portion of the latter which remained after the combuftion precipitated lime-water; and as we find here no other refults of this combuftion than water and carbonic acid, it is thence inferred that alcohol is formed of hidrogen, carbon and a certain proportion of oxigen. The prefence and the quantity of the laft mentioned principle is judged of by the portion of oxigen which it is neceffary to employ in

order

order to favour the combuftion of the alcohol, compared with that of the water obtained. Lavoifier has concluded from his experiments, that alcohol is a kind of oxide, in which the hidrogen is more abundant than in the fugar from which it has proceeded. He has not however been able exactly to determine its proportions, fince in his table of the products of the vinous fermentation, he admits more than the half of the alcohol of water ready formed in this liquid, and he does not clearly explain himfelf refpecting the reciprocal ftate of the principles which conftitute it. Though ftill far from exact, his analyfis by combuftion is however fufficient to prove that the ancient notions refpecting the nature of alcohol are falfe, and that it is neceffary to revert to that which I have already given concerning its ftate of oxide. It is not therefore a combination of a very attenuated oil, an acid and water, a fort of acid foap, as Stahl and Boerhaave had believed, nor, according to the opinion of Cartheufer and Macquer, a pure or fimple combination of water and of *phlogifton* or of hidrogen; for the *phlogifton* of Stahl has been converted into hidrogen by moft of the modern chemifts, who continue to adopt its exiftence.

71. Though I have indicated the pure alkalis as fimply foluble in alcohol, this fimple folution without alteration takes place only in the cold, or at a mild temperature; for when this folution is ftrongly heated in a retort with a convenient apparatus, we obtain products which indicate

the decompofition of this inflammable fubftance: there paffes over firft an alcohol of an agreeable and aromatic fmell, a fort of oil, much hidrogen gas, and the pot-afh which remains is charged with carbon. Some chemifts have afferted that ammonia was difengaged in this operation, and they have feen in it, as in the diftillation of foap made by the fame elevated temperature, a proof of the prefence of azote in pot-afh. Others believe that it is only a fmall quantity of pot-afh elevated with the volatile products which has produced the change in this experiment. Hence, it refults, that this operation is not yet well known, and that if it proves in general the decompofition of the alcohol, it cannot yet ferve for the determination of its principles, and ftill lefs of thofe of the pot-afh.

72. All the powerful acids act upon alcohol in a more or lefs powerful manner, and affect its decompofition with different phenomena, according to their energy, their quantity, and the temperature to which their mixture is expofed. That which is of all the moft important to be well known and its action well determined, fince it will ferve to explain that of all the others, is the concentrated fulphuric acid.

When this acid is poured upon alcohol, it firft finks to the bottom; by agitation it mixes with it, producing heat and a hiffing that proceeds from a difengagement of a portion of alcohol, already altered and aromatic, in the ftate of vapour; the mixture affumes a brown colour, and

left

left in this ſtate it forms what was formerly called *dulcified ſulphuric acid*, or *water of Rabel*, when a fourth of acid had been added to it.

When we place the retort in which the mixture is generally made upon a bath of heated ſand, and adapt two receivers to it, the firſt immerſed in a veſſel filled with cold water or ice, we obtain ſucceſſively,

a. An alcohol of an agreeable ſmell.

b. A liquid called ether, of a lively ſmell, of extreme volatility, the preſence of which is announced by the ebullition of the liquor contained in the retort, and by large ſtreaks that appear on the vault of this veſſel. Care is taken to cool the receiver with wet cloths.

c. After the ether, ſulphureous acid paſſes over, the white colour and the ſmell of which indicate that it is time to unlute the receiver, in order to have the ether ſeparate.

d. At the ſame time there is volatilized a light, yellowiſh oil, which is called *ſweet oil of wine.* The fire ought to be greatly moderated after the ether has paſſed over, as the matter contained in the retort is black, thick and ſwells conſiderably.

e. When all the ſweet oil is diſtilled, there ſtill paſſes over ſulphureous acid which becomes more and more thick, and is at laſt nothing more than black and impure ſulphuric acid.

f. It is accompanied with an odorous carbonated hidrogen gas and with carbonic acid gas.

g. It is to be obſerved that till concentrated ſulphuric acid paſſes over, water is conſtantly elevated at the ſame time with all the other products.

h. When this operation is continued with a mild fire, the reſiduum becomes at laſt intirely dried, and acquires the form and conſiſtence of a bitumen. An acid liquor and a ſubſtance dry and yellowiſh like ſulphur are obtained from this bitumen, by expoſing it to a very ſtrong fire. Citizen Baumé, who made a large ſeries of experiments upon the ſulphuric ether, long before the eſtabliſhment of the pneumatic doctrine, examined this reſiduum with much attention. He found in it ſulphate of iron, Pruſſian blue, a ſaline ſubſtance and a particular earth, the nature of which he has not determined; he aſſures us even that the yellowiſh ſublimate which it affords is not ſulphur, and that it remains white and pulverulent without inflaming upon the coals. I ſhall add to theſe details, that the reſiduum of the ether, collected after the diſtillation of this product, may again furniſh new ether if we add to it, according to the proceſs of Citizen Cadet, a third of alcohol dephlegmated by means of potaſh, and diſtil this mixture. Theſe diſtillations may be repeated ſeveral times, and thus may be extracted from a mixture of ſix parts of ſulphuric acid and of alcohol, to which fifteen parts of the latter fluid are ſucceſſively added, more than ten parts of very good ether.

73. The operation which I have just described is one of the most singular which chemistry affords, by the phenomena which it presents, and at the same time one of the most important, by the light which it may throw upon the composition of ether. Several opinions have been advanced respecting the formation of ether, of which some account must be given, in order that it may be understood in what manner Citizen Vauquelin and myself have arrived at the discovery of the true cause of etherification. Macquer, who considered alcohol as a compound of water and of *phlogiston*, thought that the sulphuric acid carried off the water from this substance, and brought it more and more near to the characters of oil. Thus, according to this opinion, there first passed over alcohol little altered; afterwards a fluid intermediate between alcohol and oil. This was the ether; and finally a real oil, because the sulphuric acid was supposed to act with the greater energy upon the principles of the alcohol, in proportion as the heat employed for obtaining the ether was more intense. Bucquet, struck by an objection which he had started against this theory, namely, that it was difficult to conceive how the sulphuric acid, charged from the commencement of its action upon the alcohol with a certain quantity of water which it had taken from this fluid, could, although phlegmatic, re-act sufficiently upon another portion of the same alcohol to reduce it to the state of oil, has proposed

posed another opinion respecting the production of ether. With Stahl and Boerhaave, he considered alcohol as a fluid composed of oil, of acid and of water. He thought that when sulphuric acid was mixed with alcohol, there resulted from this mixture a sort of bituminous fluid, which afforded the same principles, by the action of heat, as all the bitumens; that is to say, a light, highly odorous, very combustible oil, a kind of naphtha, which was the ether, a substance that has long borne the name of *naphtha*, amongst the German chemists especially, and afterwards an oil less volatile, and more highly coloured than the first, which was the sweet oil of wine. In fact, it will be seen from the properties of ether that are about to be enunciated, that this fluid has all the characters of a very attenuated oil, such as the naphtha: but this theory, which supposes alcohol to be formed of oil, of acid, and of water, can no longer be admitted, though ingenious at the time when it was proposed, for the explanation of the mechanism of the formation of ether.

74. Modern chemists, since the establishment of the pneumatic doctrine, have hitherto formed only vague ideas concerning etherification. I had asserted after them, in my preceding works, that it appeared, that the oxigen was taken away from the sulpuric acid by the alcohol, that a part of the hidrogen of the latter formed water with the oxigen of the acid, and

and that the alcohol deprived of this portion of hidrogen formed ether; but I had added, that what took place in this operation was not exactly known; and in fact, when Citizen Vauquelin and myfelf occupied ourfelves with this fubject, we arrived at other refults. The following is a fketch of our labours upon this fubject.

75. After having previoufly proved, as I have fhown elfewhere, that the concentrated fulphuric acid acts fpontaneoufly upon the vegetable fubftances, changing them into water and acetous acid at the expenfe of their compounds, and exerting on its own part only its great tendency to faturate itfelf with water, we examined the phenomena which take place in the union of this acid with alcohol; and the following are thofe which ferved as the bafis of our reafoning.

A. Equal parts of concentrated fulphuric acid, and highly rectified alcohol, mixed together, difengage a mafs of caloric capable of elevating the temperature of the mixture to feventy degrees; bubbles of gas are formed; the liquor becomes turbid, opaque, and affumes after fome days a deep red colour.

B. A combination of two parts of fulphuric acid, and one part of alcohol, elevates the temperature of the mixture to feventy-five degrees, becomes immediately of a deep red colour, paffes to black fome days after, and diffufes an odour fenfibly ethereal.

C. If

C. If we carefully obferve all that takes place in the combination of equal parts of fulphuric acid and of alcohol, expofed to the action of caloric in a convenient apparatus, fuch as is at prefent employed for preparing the ether we remark the following phenomena:

a. When the temperature is elevated to feventy-eight degrees, the liquor enters into ebullition; a vapour is produced, which is condenfed by the cold into a clear, light, and odorous liquid, which, on account of thefe properties, has received the name of ether. When the operation is fkilfully conducted, no permanent gas is developed till about half the alcohol is converted into ether.

b. If, as foon as the fulphureous acid manifefts itfelf, we change the receiver, it is obferved that no more ether is formed, but fweet oil of wine, water, acetous acid, and not an atom of carbonic acid.

When the fulphuric acid forms about four-fifths of the mafs that remains in the retort, an inflammable gas is difengaged, which has a fmell of ether, and which burns with a white oily flame. It is this gas which the Dutch chemifts have called *carbonated hidrogen gas,* or *olefying gas,* becaufe when mixed with the oxigenated muriatic acid it forms oil. At this period the temperature of the matter contained in the retort is elevated to eighty-eight or ninety degrees.

c, When

c. When the ſweet oil of wine ceaſes to run, if we change the receiver again, we ſee that there now paſſes over only ſulphureous gas, water previouſly formed, carbonic acid gas, and that there remains in the retort only a maſs, the greater part of which is ſulphuric acid thickened by coal.

From theſe phenomena, which are very conſtant, and have been well obſerved, we may draw the following reſults:

a. There is formed ſpontaneouſly, without the aid of adventitious heat, by the combination of two parts of ſulphuric acid, and one part of alcohol, a ſmall quantity of ether.

b. As ſoon as ether is formed, and at the ſame time water is produced, and whilſt the firſt of theſe compoſitions takes place, the ſulphuric acid undergoes no change in its intimate nature.

c. As ſoon as the ſulphureous acid appears, no more ether is formed, or at leaſt very little; but there then paſſes ſweet oil of wine, water, and acetous acid.

d. When the ſweet oil of wine has ceaſed to paſs, nothing more is obtained than ſulphureous acid, carbonic acid. and finally ſulphur, if we diſtil it to the end.

The operation of making ether, as it is practiſed, is therefore really divided into three epochas: the firſt, in which a ſmall quantity of ether and of water are formed without the aid of an adventitious

ventitious heat, namely, between feventy and feventy-two degrees; the fecond, by which the whole quantity of ether which is obtained is difengaged without being accompanied by fulphureous acid, at feventy-eight degrees of temperature; finally, the third, in which the fweet oil of wine, the olefying gas, the acetous acid, the fulphureous acid, and the carbonic acid, are produced, whilft the mixture is elevated from eighty-eight to ninety degrees of temperature by heat communicated to it. Thefe three periods have nothing in common with each other, except a continual formation of water from the beginning to the end of the operation.

Refting upon thefe well-confirmed obfervations, we have eftablifhed the theory of etherification in the following manner: In the cafe where the ether is formed by the fimple mixture of alcohol and of fulphuric acid, without the aid of adventitious heat, a formation which is announced by the heat as well as by the black precipitate, the carbon which is feparated without production of fulphureous acid, proves that the fulphuric acid acts upon the alcohol in a very different manner from what has hitherto been believed. In fact, this acid cannot be decompofed at this temperature by the carbon; experience has fhown that no action takes place in the cold between thefe two bodies. Neither is the entire alcohol decompofed; for then fulphureous

phureous acid would be formed, of which it is known that no trace appears at the beginning of the operation.

We must therefore have recourse to an action of another order; namely, the powerful affinity which sulphuric acid exerts upon water; it is this which determines the union of the constituent principles of the water existing in the alcohol, with which this acid is in contact; but this action is limited: there is soon established an equilibrium of affinities, the effect of which is to maintain the new combinations in a state of repose.

If it be proved that ether is formed by the mixture of any given quantities of sulphuric acid and alcohol, it evidently follows that we might completely change a mass of alcohol into ether, water, and vegetable acid, by sufficiently elevating the sum of the sulphuric acid; and it is equally evident that this acid would experience no other alteration than that of being diluted with water.

It ought not to be inferred from this theory, that the ether is only the alcohol, minus the oxigen, and hidrogen; for there is separated at the same time a quantity of carbon proportionally larger than that of the hidrogen; and it is easily conceived that the oxigen, which combines in this circumstance with the hidrogen to form the water, did not saturate only this hidrogen in the alcohol, but that it at the same time saturated in it the carbon that is precipitated: thus,

thus, inftead of confidering the ether as alcohol minus the hidrogen and oxigen, we ought, taking account of the carbon that is precipitated, and of the fmall quantity of hidrogen contained in the water that is formed, to confider it as alcohol, plus hidrogen and oxigen. Such is the theory of what paffes in the fpontaneous action between the fulphuric acid and alcohol without the addition of extraneous heat.

When the mixture of fulphuric acid and alcohol is fubjected to the action of heat, the mode of the etherification is more complicated and its refults more numerous.

Firft, we muft obferve that this mixture, in equal proportions, does not enter into ebullition below the temperature of feventy eight degrees, whereas alcohol alone boils at fixty-four degrees; whence it is to be concluded that the alcohol is retained by the attraction of the fulphuric acid which fixes it. We muft compare what then takes place in it with what happens to every other vegetable matter expofed to the fire, the principles of which are volatilized according to the order of their affinity for caloric, carrying along with them a fmall quantity of the more fixed elements: thus, in proportion as the fulphuric acid attracts the alcohol and the water, the formation of which it favours, the ether which is developed attracts the caloric and is volatilized, and when the greater part of the alcohol has been changed into ether, the mixture becomes more denfe, the heat which it acquires

acquires is more confiderable, and the affinity of the fulphuric acid for the alcohol not yet decompofed being augmented, the principles of this acid feparate; fo that, on the one hand, its oxigen feizes the hidrogen of the alcohol, and forms water, which is gradually volatilized, whilft, on the other, the ether retaining a larger quantity of carbon with which it can be volatilized at this temperature, gives rife to the *fweet oil of wine*, which ought to be confidered as an ether more highly charged with carbon, which is proved by its fuperior weight, its lefs confiderable volatility, and its yellow colour.

With the aid of this fimple theory, which is only the refult of the facts, we have been led to conclufions ufeful to the chemical and pharmaceutical art, of which the following is a fketch.

a. The formation of ether is not to be attributed, as had hitherto been thought, to the immediate action of the principles of the fulphuric acid upon thofe of the alcohol, but to a real re-action of the elements of the latter upon each other, and particularly of its oxigen and hidrogen, occafioned only by the fulphuric acid.

b. We might, ftrictly fpeaking, change any given quantity of alcohol into ether, without the aid of heat, by fufficiently augmenting the proportion of fulphuric acid.

c. The ordinary operation is divided into two principal periods with refpect to the alteration of the alcohol; in one of which nothing elfe is formed

formed than ether and water, in the other ſweet oil of wine, water, and acetous acid.

d. During the formation of the ether, the ſulphuric acid is not decompoſed, and the ſweet oil of wine is not formed; as ſoon as this appears, no more ether, or at leaſt but very little, is diſengaged, and at the ſame time the ſulphuric acid is decompoſed by the hidrogen alone: hence reſults the ſulphureous acid.

e. We may avoid the formation of the ſweet oil of wine by maintaining the temperature between ſeventy-five and ſeventy-eight degrees, by means of a well-conducted addition of ſome drops of water in the retort.

f. Finally, alcohol differs from ether by its containing more carbon and leſs hidrogen and oxigen; and the ſweet oil of wine ſtands nearly in the ſame relation to ether as the alcohol does to it.

76. The ether obtained by the proceſs that has been deſcribed, and which is called *ſulphuric ether*, is not very pure; it is combined with alcohol and with ſulphureous acid. In order to rectify it, it is diſtilled in a retort on the ſand-bath with fixed alkali or with magneſia. Either of theſe baſes combines with the ſulphureous acid, and the ether paſſes off very pure by the gentleſt heat. If we ſeparate the firſt half of this product, we obtain the moſt agreeable and the beſt rectified ether.

Ether is a lighter fluid than alcohol, of a ſtrong, aromatic, and very diffuſible ſmell, of

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a hot and pungent tafte. It is fo volatile that on pouring it out or agitating it, it is inftantaneoufly diffipated. It produces fuch a degree of cold in its evaporation, that we may congeal water in a veffel, by wrapping it round with cloths, and evaporating ether upon them. It is reduced into a fort of ethereal gas which burns with rapidity. The air that holds ether in folution may pafs through water without ceafing to be inflammable and odorous. This kind of combuftible gas is employed for electrical experiments and for charging Volta's cannon.

Ether inflames very eafily when it is heated in the free air, or when an inflamed body is brought into contact with it; the electric fpark likewife kindles it. It emits a white and very luminous flame, and it leaves a black, feemingly coaly mark upon the furface of the bodies which we expofe to its flame. Lavoifier has afcertained that acid is formed during the combuftion of this liquor, and Scheele, that the refidue of ether, burned upon a fmall quantity of water, contains fulphuric acid.

Ether diffolves in ten parts of water, according to Citizen Lauraguais. The phenomena which ether would prefent with all the faline fubftances have not yet been examined in detail; we are only well acquainted with the action of fome of the acids upon this inflammable liquid. Lime and the fixed alkalis do not appear to be fufceptible of altering it. Cauftic ammonia mixes with it in all proportions, and forms with it a ſubſtance, the mixed odour of which might be very uſeful in faintings and ſpaſmodic affections. The ſulphuric acid becomes ſtrongly heated with ether, and it may convert a conſiderable part of it into ſweet oil of wine by diſtillation. The fuming nitrous acid excites in it a conſiderable efferveſcence; and the ether appears to become more conſiſtent, more coloured, and more oily in this experiment.

Mixed with the muriatic ſolution of gold, it retains a part of this metal for ſome time, and ſeems then to act like the volatile oils, which likewiſe retain a portion of oxide of gold; but at the end of ſome days the gold ſeparates in the brilliant, metallic, ductile, and cryſtalline form.

Ether diſſolves the volatile oils and the reſins like alcohol; and phyſicians frequently employ etherated tinctures. It diſſolves the ſoftened caoutchouc well, if previouſly ſwelled in boiling water, and cut into ſmall fragments. This ſolution, as it evaporates, leaves a layer of pure and elaſtic caoutchouc upon the bodies on which it has been ſpread.

77. The nitric acid, and eſpecially the nitrous acid, act in a much more rapid manner than the ſulphuric upon rectified alcohol: here, inſtead of promoting the re-action by heat, every attempt is made to moderate it, either by diluting the two liquids, or by cooling their mixture.

Navier,

Navier, a phyſician at Chalons, is the firſt who has given an eaſy and moderately expenſive proceſs for preparing the nitrous ether. According to this chemiſt, we take a very ſtrong *Sèvres* or ſtone-bottle, pour into it twelve parts of pure and well-rectified alcohol, and immerſe it in cold water, or, which is ſtill better, into ice; then add at different times, ſhaking the mixture each time, eight parts of concentrated nitric acid, but in part nitrous; the bottle is to be well cloſed with a good cork, tied over with leather; this mixture is left to ſtand in a remote place, in order to prevent the accidents which ſometimes ariſe from the breaking of the bottles. After ſome hours, bubbles riſe from the bottom of the veſſel, and drops collect at the ſurface of the liquor which gradually form a ſtratum of real ether. This diſengagement takes place during four or ſix days. When no motion is any longer obſerved in the liquid, the ſtopper is perforated with a bodkin, in order to let a certain quantity of nitrous gas eſcape, which, without this precaution, would iſſue out with rapidity in uncorking the bottle, and carry with it the ether which would be loſt. When the gas is diſſipated, the bottle is gently uncorked; the liquor which it contains is poured into a funnel; the reſiduum is ſeparated, by preſſure of the finger, from the ether which ſwims above it, and the latter is received into a ſeparate bottle.

78. Mr. Woulfe, an Engliſh chemiſt, has given another proceſs for preparing the nitric ether.

It confifts in employing very large veffels, in order to prefent a large fpace to the elaftic fluids which are difengaged. We take a matrafs of white glafs, from eight to ten litres, terminated by a neck about two metres and a half in length; this is placed upon a three-legged fupport, fufficiently high for a chafing-difh to be placed beneath it; to the neck of this matrafs a tubulated capital is fitted, to the beak of which a tube of glafs is adapted, of equal length with the neck of the matrafs: this laft is received by its lower extremity into an adopter with two necks, perforated below with a tubulure to which a bottle is fixed; to the third neck of this veffel are added the bottles which conftitute Woulfe's apparatus that has been already feveral times defcribed. When all thefe veffels are well luted, equal parts of rectified alcohol and of fuming nitrous acid are poured into the matrafs by the tubulure of the capital; the capital is then clofed with a glafs ftopper which is fecured with a leather bound round with packthread. As foon as the mixture is made it becomes much heated; vapours are difengaged from it, which rapidly pafs through the neck of the matrafs; and the latter being heated till the liquor which it contains boils, with the aid of the chafing-difh placed under it, nitric ether paffes into the matrafs which ferves as the receiver. This procefs, though very ingenious, has feveral inconveniences; it requires a confiderable time to fix the apparatus, which is very dear and

very

very embarraſſing; beſides which, it is attended with danger; for, notwithſtanding the ſpace given to the vapours, they are diſengaged with ſuch rapidity, that the apparatus frequently breaks with a loud exploſion. In five operations of this nature which I have witneſſed or aſſiſted in, from 1772 to 1778, I have twice ſeen the veſſels fly in pieces with a violent exploſion.

79. Mr. Bogues publiſhed, in 1773, another method of preparing the nitric ether. He adviſes to mix in a glaſs retort, of a capacity to contain 8 kilogrammes (about 20lbs.) of water, half a kilogramme of alcohol, with the ſame quantity of nitric acid, diluted ſo as to give only 24 degrees by the areometer for the acids; to adapt to the retort a matraſs capable of containing twelve kilogrammes of water; to afford a paſſage to the gas by adjuſting two quills to the junction of the lutes, and to diſtil with a very gentle fire, immerſing only a very ſmall part of the retort in the ſand. By this method he has obtained a little more than a third of the weight of the alcohol of ſufficiently pure nitric ether. It appears from what Rozier ſays in his Journal de Phyſique, that Mitouard employed, ſince 1770, a proceſs much reſembling that of Mr. Bogues. This chemiſt put four parts of fuming ſpirit of nitre with twelve parts of alcohol to diſtil in a retort, which he ſuffered to reſt but very lightly upon the ſand, and by this means, which appears to be the moſt ſimple of all, he obtained nitric ether ſimilar to that of Navier.

 80. Finally

80. Finally Citizen Laplanche, apothecary at Paris, has successively contrived two methods for preparing the nitric ether by sufficiently convenient processes. The first consists in putting nitre into a tubulated retort of stone-ware, to which is adapted either one large matrass or two connected together, and pouring through the tubulure first concentrated sulphuric acid and afterwards alcohol. The sulphuric acid disengages the nitric, which re-acts upon the alcohol, and forms almost immediately nitric ether. As it might be suspected that the ether prepared by this process was in part sulphuric, he has substituted instead of this first method a second very ingenious process. He adapts to a tubulated glass retort, into which he has put well dried nitre, an adopter and a matrass which communicates by a curved tube with an empty bottle; the latter communicates by the aid of a syphon, into another bottle which contains alcohol of the most perfect kind to the amount of half the weight of the nitre. The whole being well luted, and the retort placed upon a bath of ashes, concentrated sulphuric acid, also to the amount of half the weight of the nitre, is poured upon the nitre through the tubulure of this last vessel; the retort is closed with a glass stopper; the fire is applied till ebullition is produced, and in this state it is kept till no more vapours pass over. In this experiment, the sulphuric acid disengages that of the nitre, part of which passes into the matrass and part into the second flask.

When

When the operation is completed, the matrafs contains fuming nitrous acid, the retort fulphate of pot-afh, and the fecond flafk a liquor, etherated by the action of the vapour of the nitric acid upon the alcohol. This laft liquor is diftilled in a retort with a fimple receiver, and only two thirds of the product are taken. This product is again diftilled with a fifth of fuming nitrous acid which is gradually poured upon it by means of a glafs funnel with a long pipe; only two thirds of it are taken; finally, this fecond product is rectified upon pot-afh, dividing the product of the ethereal liquor into two parts; the firft is very pure nitric ether, the fecond forms a kind of anodyne nitrous mineral liquor. The refidues of the two rectifications form what was formerly called *dulcified fpirit of nitre.*

81. The nitric ether obtained by all thefe different proceffes is a yellowifh fluid, equally volatile, and equally evaporable with the fulphuric ether; its fmell is fimilar to that of the latter, though ftronger and lefs agreeable; its tafte is hot and more difagreeable than that of the fulphuric ether; it is frequently of a yellow colour; it caufes the ftoppers of the bottles in which it is inclofed to fly out, becaufe a large quantity of gas is continually difengaged from it; it conftantly gives a red and yellow tinge to the linen of the corks with which it is compreffed; it diffufes whilft burning a more brilliant flame and a thicker fmoke than the fulphuric ether;

 it

it alſo leaves a coal ſomewhat more abundant; like the ſulphuric ether, it ſeparates gold from its ſolution and becomes charged with a certain quantity of it. When it is kept for a long time in a cloſe veſſel, water containing a ſmall quantity of oxalic acid is formed at the bottom of this ether: it is rendered colourleſs by diſtilling it from the alkalis; ſugar has ſucceeded with Citizen Deyeux in effecting this purification, and this body retained a burning acrid oil which he believes to be analogous to the ſweet oil of wine, and formed during the diſtillation of the ether; he adds that it is produced more ſpeedily by the action of the nitric acid than by that of the ſulphuric, and that it is diſengaged at the ſame time with the ether, which is the cauſe of its colour: he has alſo found that by mixing ſixteen parts of water with one part of nitric ether, in a bottle provided with a tube, the nitric gas which it contains is ſeparated from it by a ſpontaneous efferveſcence, and that, when once deprived of this gas, the nitric ether may be kept like the ſulphuric, without breaking the veſſels in which it is incloſed. It is in this manner that he preſcribes it to be rectified by means of ſugar, and deprived of gas by means of water, for medicinal uſe.

82. The reſiduum of nitric ether is of a yellow colour; its ſmell is acid and aromatic; its taſte pungent and reſembling that of diſtilled vinegar. When diſtilled it affords, according to Citizen Baumé, a clear liquor, of a more pleaſant

ſant ſmell than the nitric ether, of an agreeable acid taſte, which reddens the ſyrup of violets, unites with water in all proportions, and efferveſces with the carbonate of pot-aſh: this is acetous acid mixed with a little ether. There afterwards remains in the retort a matter of an amber-yellow colour, friable, reſembling amber, attracting the humidity of the atmoſphere, and acquiring a pitchy conſiſtence, and diſſolving in water without rendering it mucilaginous. This ſubſtance, which Citizen Baumé calls *ſaponaceous gum*, affords by the retort ſome drops of an acidulous liquor, which is very clear, of an oily conſiſtence and a ſlight empyreumatic ſmell. After the diſtillation a coal remains which is ſpongy, brilliant, without taſte, and very fixed in the fire. Bucquet ſays that if we evaporate the liquor which remains after the formation of the nitric ether, it aſſumes the conſiſtence of a mucilage, and that there are formed in it after a longer or ſhorter ſpace of time, ſaline cryſtals, much reſembling hairy caterpillars, which have been called *Hiœrne's cryſtals*, after the name of the chemiſt who firſt deſcribed them; it is now known, according to the experiments of Mr. Hermſtaedt, that they are oxalic acid. It is evident, according to all theſe details, to which we may add that carbonic acid gas paſſes over during the whole of the action of the nitric acid upon the alcohol, that this action does not differ from that of the ſulphuric acid, except in the circumſtance that the

carbon

carbon which is precipitated by the latter is dissolved and burned in the oxigen of the former; that oil is formed more quickly and more abundantly; that the etherification proceeds from the same cause, and that oxalic and acetous acids are formed at the same time with the ether, the oil, the water and the carbonic acid. The rapidity of this decomposition, and the gases which are disengaged whilst it takes place, render the etherification by the nitric acid much more tumultuous than that by the sulphuric, and this is the cause why it is so frequently accompanied with explosion, and the bursting of the apparatus, when it is made with a too highly concentrated acid.

83. The muriatic acid has no sensible action upon alcohol; this acid is dulcified, either by the simple admixture of that liquid, or by distillation with it, as the two others are when mixed in small quantity with alcohol. Citizen Baumé, in his dissertation upon ether, says he has obtained a small quantity of muriatic ether by causing the muriatic acid and alcohol to meet in vapour. Ludolf and Pott have employed the super-oxigenated and sublimed muriate of antimony, or the *butter of antimony*, with this view. Mr. de Bormes has prescribed to dissolve oxide of zinc in muriatic acid, and to distil this salt concentrated by evaporation in close vessels with alcohol. This process affords muriatic ether with sufficient facility.

But

But no one, previous to the chemical revolution, had followed up this work with so much attention as Courtanvaux, of the Academy of Sciences; he succeeded in preparing the muriatic ether by the following process: One part of alcohol, with nearly three parts of super-oxigegenated muriate of tin, or the fuming liquor of Libavius, are poured into a glass retort; a very violent heat is excited, and a white suffocating liquor rises, which disappears as soon as the liquor is agitated; an agreeable smell is then disengaged, and the liquor assumes a yellow colour. The retort is placed upon a bath of hot sand; two matrasses are luted to it, the last of which is immersed in cold water. First dephlegmated alcohol passes over, and the ether rises soon after: this is perceived by its agreeable smell, and by the streaks which it forms upon the roof of the retort. As soon as this smell changes, and becomes strong and suffocating, the receiver is changed, and the distillation is continued; a clear acid liquor is obtained, with some drops of *sweet* oil swimming upon it, which is succeeded by a yellow matter of a butyraceous consistence, a real muriate of tin, and at last a brown, heavy liquor, which exhales white vapours in great abundance: there remains in the retort a grey pulverulent matter, which is an oxide of tin. The ethereal product is poured into a retort upon carbonate of pot-ash; a lively effervescence takes place, and a very abundant precipitate is formed, which

which proceeds from the oxide of tin which the acid had carried away with it during the diſtillation: a ſmall quantity of water is added, and diſtillation is performed with a gentle heat; about the half of this ethereal product is obtained. All the liquors which paſs after the muriatic ether are highly charged with oxide of tin; they attract the moiſture of the air, they unite with water without forming any precipitate. It was not known to what we ought to attribute the very rapid action of the muriate acid contained in the *fuming liquor* of Libavius upon the alcohol, whilſt the pure acid exerted no action at all upon it; but it is evident that this action is owing to the circumſtance that this acid is in the ſtate of oxigenated muriatic acid in this metallic muriate, and that it is to the exceſs of the oxigen that we ought to attribute the property which it poſſeſſes of converting the alcohol into ether. Such is the theory which was firſt advanced by me in 1781, and which has been confirmed by the labours of Citizens Berthollet and Pelletier, as I ſhall proceed to ſhow.

84. Citizen Laplanche has propoſed, for preparing the muriatic ether, to pour into a tubulated retort ſulphuric acid and alcohol upon decrepitated muriate of ſoda. The muriatic acid gas, diſengaged by the ſulphuric acid, meets in the receiver with the alcohol in vapour, and combines with it. He aſſures us that there reſults an etherated acid, which is rectified upon

pot-aſh,

pot-ash, in order to obtain the pure ether from it; but it is probable that if a little ether is formed in this process, it proceeds only from a small portion of oxigenated muriatic acid formed in the operation. Pelletier has succeeded in producing muriatic ether by distilling in a large tubulated retort oxide of manganese, muriate of soda, concentrated sulphuric acid, and rectified alcohol. The ether, which is obtained by this process, forms half the weight of the alcohol that has been employed. Citizen Berthollet has discovered that the same ethereal liquor is obtained by distilling with a mild heat alcohol saturated with oxigenated muriatic acid gas; and it has since been obtained by distilling upon the oxide of manganese a mixture of highly rectified alcohol and well concentrated muriatic acid. Every thing proves therefore, that the etherification proceeds from the oxigen added to the muriatic acid.

The muriatic ether is very transparent and very volatile; it has nearly the same colour as the sulphuric; it burns like it, and emits similar fumes, but it differs from it by two properties; the one that it exhales, in burning, a pungent smell as strong as the sulphureous acid; the other, that it has a styptic taste similar to that of alum. These two phenomena are undoubtedly owing to some foreign bodies which it contains; for every thing indicates that ether is in itself an identic substance, a constant product of the decomposition of the alcohol, by whatever acid and even by whatever re-agent

it

it has been formed; for we ſhall ſoon ſee that the action of an acid is not indiſpenſably neceſſary to its production.

85. It has been often tried to produce ethers with the phoſphoric, the tartarous, &c. acids; but all theſe attempts have been fruitleſs, becauſe theſe acids have too little attraction for water to favour its production by the decompoſition of the alcohol, as the ſulphuric acid does, or have too ſtrong an adheſion with oxigen to ſuffer this principle to ſeize upon thoſe of the alcohol, or are too eaſily decompoſed themſelves by the temperature at which the ethers are generally prepared, to be able to re-act upon the alcohol, and effect its etherification. Beſides which, when chemiſts endeavoured with a ſort of obſtinacy to form ethers with every acid, either new, or that had not yet been examined as to its action upon alcohol, it was the general opinion that each ether was different from all the reſt; but it is now known, that excepting the admixture of a ſmall quantity of the acid employed, ether is the ſame body by whatever acid it may have been formed.

86. Alcohol is decompoſed by thoſe metallic oxides which moſt eaſily relinquiſh their oxigen, and it even ſometimes paſſes by the action of heat into the ſtate of vapour in this decompoſition, as Citizen Vanmons has diſcovered. We here ſee the ſame fact, and conſequently the ſame theory as in the action of the nitric and of the oxigenated mu-

riatic

riatic acid upon alcohol. We obtain the ſame reſult, and even a much more ſtriking effect, by the double decompoſing attraction which the metallic ſolutions exert upon alcohol, when it is diſtilled with theſe bodies. By diſtilling theſe mixtures, we obtain proportions of ether ſo much the larger as the ſolutions are more concentrated, and as the metallic oxides which they contain more eaſily relinquiſh their oxigen. It is eſpecially with the nitrates of mercury, of ſilver, of lead, and with the ſuper-oxigenated metallic muriate, that theſe effects are the moſt energetic.

87. Finally, the decompoſition of alcohol by its inflammation is modified in a more or leſs remarkable manner in the colours of the flame which it affords; by a great number of bodies which it holds in ſolution, or which are mixed with it, and though the real cauſe of theſe modifications are not yet known, they are in themſelves ſufficiently ſtriking and ſingular to deſerve at leaſt to be carefully deſcribed. Thus the boracic acid gives to the colour of the flame of alcohol a remarkable yellowiſh-green caſt; the ſoluble ſalts of ſtrontian, a purple colour; thoſe of barites, a pretty deep yellow; thoſe of iron, light reds; and thoſe of copper, blueiſh greens, very different from the tinge produced by the boracic acid.

E. Species.

E. *Species.*

88. Though chemists have for some time believed that the alcohol extracted from different fermented liquors was different; though they have especially distinguished the brandies of wine, that of beer, called *malt spirits*, the alcohol of cherries, designated by the name of *Kirchenwasser*; the brandy of cider; *rum*, or the brandy of the sugar-cane; *arrack*, or the brandy of rice; yet it is well known at present that all these products are one and the same, possessing identical properties, and presenting exactly the same chemical phenomena.

89. However, for domestic purposes, for the uses of the arts, and especially for the delicacy of our organs, it is indispensably necessary to admit the distinction of the species of which I have just spoken, since their different taste, their very diversified inflammability, lightness, and solvent properties, render each of them useful in different circumstances. But these modifications depend much more upon the manner in which they have been prepared, and upon the few precautions that have been taken in their distillation, than upon their peculiar nature. In order to convince ourselves of this, it is sufficient to observe, that the brandy extracted from wines is not the same in its taste, its smell and its strength, in the different countries where

it is prepared, though the primitive liquor which furnishes it be identical, because its distillation is conducted in a different manner. Still more must this happen with fermented liquors, charged with much extractive and mucilaginous matter, such as the beers and the ciders, which, when they are strongly heated, as is done in most distilleries, become thick, burn or char at the bottom of the alembics, and thus afford acrid, odorous, empyreumatic brandies, as they carry along with them a portion of oil in the distillation. It is known with what energy alcohol retains the small quantity of oil capable of giving it strong smells, and a taste foreign to its own. It is known that when once saturated in this manner by distillation it is impossible to deprive it of them, and this sufficiently explains all the various properties, so sensible to our organs, and nevertheless so inconsiderable in our chemical operations; which we meet with in the different kinds of brandies and of alcohol of commerce.

F. *Uses.*

90. The uses of alcohol are extremely numerous. Its property of supporting and raising the diminished strength of the body, of augmenting the energy of the contractile fibres, the motion of the circulation, and the activity of the whole animal system, gives it a place amongst the most important remedies. It is rarely administered alone,

alone, at least not unless reduced to vapour, in order to introduce it with the air into the lungs, and cause it to act upon the relaxed fibres or the ulcers with which they may be afflicted. It is combined with a multitude of different substances, in order to add to its virtues and to adapt it to the indications which we wish to fulfil. It is rendered very solvent by pot-ash in the acrid tincture of tartar and the *lilium*; very antiseptic with camphor, antispasmodic with the small portion of volatile oil which gives it smell and modifies it, in what are improperly termed *distilled spirituous waters*, very astringent with the addition of a quarter of its weight of sulphuric acid, which constitutes the water of Rabel. It is very stomachic and cordial when combined with resins and oxigenated extractives; as it is in the artificial balsams, the tinctures and the elixirs, or the *spirituous* compounds, of which such a number of varieties are enumerated in the books of medical receipts and formulæ.

91. Alcohol reduced to the state of ether is one of the most powerful stomachic, tonic and antispasmodic remedies, as it acts by being suddenly reduced into vapour in the stomach, where it is received upon a large surface at once, and upon almost the whole of the nervous system. It has been especially recommended as a solvent of biliary calculi; but it is evident that it acts in this case much more by its sedative property than by a real solvent quality, since the slightest knowledge of anatomy is sufficient

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to ſhow that it cannot penetrate in ſufficient abundance into the *ductus choledochus* and *cyſticus* to act immediately upon the concretions contained in the gall-bladder. Ether intoxicates more powerfully and in a much ſmaller doſe than alcohol. By mixing it with the firſt aromatic alcohol which paſſes in the diſtillation with ſulphuric acid, and with ſome drops of volatile oil which paſſes after it, the *anodyne mineral liquor of Hoffman* is prepared, which is much inferior to the ether itſelf, and acts much more feebly and unequally. What is called in pharmacy *nitrous anodyne mineral liquor* is the product which ſucceeds the *nitrous* ether in the diſtillation. As to the muriatic ether, it is a very bad medicine, as it is never uniform, frequently contains acid, and is much leſs etherated than the two preceding. The common or ſulphuric ether, well rectified, is preferable to all others.

92. It is on account of its tonic and corroborant virtues, that alcohol is ſo frequently employed in the preparation of very agreeable liquors which are taken after meals to promote digeſtion. The name of *ratifias* is given to the infuſions of a number of ſubſtances in brandy, ſweetened with ſugar, and more particularly that of *liqueurs*, to the combinations of well rectified alcohol with volatile oils and ſyrups, in different proportions. The ſyrup furniſhes the water and the ſugar which ſoften the burning acrimony of the alcohol; the volatile oil ſupplies

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the perfume; and when theſe ſubſtances are combined in proper proportions, ſo that no flavour is too predominant; when the combination is very intimate, which it eſpecially becomes in the courſe of time, they produce extremely agreeable beverages. They are varied without limit, according to the volatile oil that is uſed; thoſe of vanilla, of the roſe, the orange, the citron, the clove, the nutmeg, cinnamon, aniſeed, are preferred to moſt others, on account of the ſtrength or pleaſantneſs of their fragrance. They are frequently combined with each other, and ſometimes even in large quantities, and in this caſe care is taken to compound them in ſuch a manner that none may predominate over the reſt. In general they are prepared with one part of rectified alcohol, two parts of water, one of refined ſugar, and ſome drops of volatile oil. Sometimes the alcohol is made to act immediately upon the intire vegetable matters, in order to give it more of what is called the flavour of the fruit. They are coloured with cochineal and ſaffron. Theſe very pleaſant liquors are uſeful only when taken moderately and in ſmall quantities; their abuſe is pernicious and dangerous: inſtead of ſtrengthening they then weaken the powers of the body and eſpecially thoſe of the ſtomach.

93. Alcohol, by the property which it poſſeſſes of eaſily diſſolving the volatile oils, of carrying them off by diſtillation, ſo as to form highly odorous and aromatic liquors, is very much employed

ployed in the perfumer's art. It is with this substance that they prepare the pleasant liquids known by the name of scented waters, the *eau de bouquet*, the *eau de millefleurs*, the *pots pourris*, &c.: they also combine several of them together. Benzoin, storax, ambergris, musk, vanilla, are frequently employed in these compositions used for the toilet. These are also products of art which ought never to be employed but with reserve and moderation, as it becomes necessary to augment the dose when once habituated to the abuse of them; and by the continual effect of perfumes the organs become weakened and suffer a remarkable relaxation.

94. Alcohol is employed as a combustible to supply table-lamps, to afford brilliant flames in public spectacles, and for performing a great number of philosophical and chemical experiments. It is particularly employed as a solvent in the preparation of the finest and the most costly drying varnishes. These varnishes are in general saturated solutions of transparent resins that are dry, little coloured, or even intirely transparent, such are copal, sandarach, mastich, olibanum. Alcohol is too costly to serve for dyeing in the large way; but it is sometimes employed for dyeing silks and ribbands.

95. It is one of the most useful solvents to chemists. It is especially applied to the separation of the deliquescent salts in the analysis of the residuums of mineral waters, of the ashes of

 plants

plants, &c. to the extraction and purification of pot-ash, soda, &c.; to the examination of the vegetable matters, after having treated and exhausted them with cold and hot water; to the treatment of some animal substances; to the precipitation of salts that are insoluble in alcohol though soluble in water, &c. &c.

SECTION VI.

Of the Causes or the Mechanism of the Vinous Fermentation, and of the Formation of Alcohol.

96. THOUGH I have shown in the two preceding paragraphs that the alcohol did not exist ready formed, or intirely composed in the wine; though I have considered it as a remote product of the vinous fermentation, it is however no less true that it proceeds from this fermentation; that without it it would not exist, and that it is really formed by this process, since a fermented vinous liquor is requisite for obtaining it. It is no less evident that it proceeds from the sugar, because it is indisputably necessary that a liquor should be saccharine in order to become vinous, and since, when this liquor has passed into the state of wine, it no longer contains any saccharine substance.

97. Chemists

97. Chemifts have long known that alcohol is formed at the expenfe of the faccharine matter: it is only fince the pneumatic doctrine, and by the fine experiments that have ferved to eftablifh it, that the hope of determining the mechanifm by which this kind of change is effected, has been conceived and already in part realized. Lavoifier is the firft and almoft the only chemift who has occupied himfelf with it; and though fomething is ftill wanting, on the fcore of precifion, to the ingenious refults which he has given us refpecting this transformation, yet thefe refults are fufficiently fair and conclufive, efpecially when compared with the improbable hypothefes which had been given before him, to authorize our confidering this part of the fcience as greatly advanced, and very well calculated to diffufe great light over the vegetable analyfis.

98. This illuftrious chemift begins by fhowing, that in the vinous fermentation, as in every chemical operation, a real equation takes place between the principles of the body which ferments, and thofe which it affords after having fermented: that the juice of the grape, and more particularly the fugar, affording by fermentation, on the one hand carbonic acid, and on the other alcohol, we muft thence conclude the fugar to be = carbonic acid + alcohol; and that by knowing well the nature of each of thefe bodies and that of the fugar, we may exactly appreciate what happens during this fermentation,

tion, or in what the change of nature, which it effects may consist. According to this view, knowing the nature of the sugar in which he had found 0,64 of oxigen, 0,28 of carbon, and 0,08 of hidrogen, he fermented it with a small quantity of yeast which he had also examined: his experiment was made in an ingenious apparatus, in which he collected exactly the carbonic acid disengaged, and lost none of the products of the fermentation. Without entering here into the detail of the proportion of these products, with respect to which something is wanting in accuracy, as must have been the case in a first experiment, I shall here exhibit only the general results, which alone are of interest to the general progress of the theory, and conduct us to the knowledge of the mechanism of fermentation.

99. In calculating the proportion of the primitive principles contained in the 0,96 of sugar totally decomposed in his experiment, Lavoisier found that this quantity of oxigen, of carbon, and of hidrogen was sufficient for forming all the alcohol, all the carbonic acid, and even the portion of acetous acid which he obtained. Hence he concluded that it is not necessary to suppose any decomposition of the water, as he had done at first, for explaining the composition of these two principal products, the alcohol and the carbonic acid; but that the mechanism of the vinous fermentation consists only in a change of equilibrium effected in the constituent principles

of

of the ſugar, and in a new union under another order of theſe principles; a change favoured only by the preſence of the water and of the caloric, and commenced more eſpecially by the ferment of the yeaſt which he had employed.

100. The effects of this fermentation are reduced in this theory founded upon experiment, to the ſeparation of the ſaccharine matter into two new compounds; to the oxigenation of the one at the expenſe of the other, to form carbonic acid, a neceſſary product of the vinous fermentation; and to the diſoxigenation of the other in favour of the firſt, in order to compoſe with it the inflammable ſubſtance called alcohol; ſo that, ſays he, if it were poſſible to re-combine theſe two products, the alcohol and the carbonic acid, in the ſame proportions in which they reſpectively formed the ſugar that has fermented, the ſugar would be reproduced ſuch as it was previous to the fermentation. According to him, the hidrogen and the carbon do not exiſt in the oily ſtate in the alcohol, but they are united with a proportion of oxigen, which, being maintained with them at a certain equilibrium of compoſition, conſtitutes a new ſpecies of oxide ſtill very inflammable, and which, when decompoſed by paſſing it, as I have already indicated, through a red-hot porcelain tube, again forms water and carbonic acid, and depoſits a portion of carbon.

101. Thus the alcohol, which is ſugar—a notable quantity of carbon and of oxigen + an equally notable quantity of hidrogen, to the exact

exact knowledge of which nothing more is wanting than that of its primitive principles ;—this alcohol, which is sugar, de-carbonated and disoxigenated or hidrogenated sugar, comports itself exactly as such in all the experiments to which it is subjected. It is much more light and volatile than sugar on account of its proportion of hidrogen; it burns without fumes and without soot; it affords a large quantity of water in its combustion. It is also evident, that when we consider the mechanism of the vinous fermentation in the comparative properties of its products, we may regard it as two operations performed at the same time, as a slow and successive combustion of the carbon, and a decombustion of the other part of the sugar, which then becomes more combustible, and forms the alcohol.

102. Accordingly, Lavoisier has terminated these fine inquiries upon fermentation, by remarking that this operation presents a new means of analyzing sugar; that supposing a vegetable matter subjected to fermentation to be well known, we may consider it with respect to the products which it affords, as a real algebraic equation, and that each of the products that compose it may give a real value, which enables us to rectify the experiment by the calculation, and the calculation by the experiment. It is thus, as an important means of analysis, that I have represented the study of the vegetable fermentations; and it must here appear,

appear, that in order to become perfectly acquainted with the vinous fermentation and its products, to arrive by this knowledge at that of its real mechanism, nothing more is necessary than to find the exact relation of the proportions between the principles which combine with each other; and this is what may be hoped from further chemical researches, pursued with the same spirit, and with the same apparatuses which Lavoisier has already so usefully employed.

The general result of what is already known concerning the vinous fermentation is, that the original intention of nature in giving rise to it, has been to reduce the vegetable compound to a more simple order of composition, since one of the products of this movement is already a binary compound, namely, the carbonic acid. We shall acquire a series of irrefragable proofs of this leading truth in the examination of the other successive fermentations on which I shall treat in the subsequent articles.

Article V.

Of the acid Fermentation and of its Products, or of the acetous Acid.

1. THE acid fermentation was considered as the second degree of general fermentation by Boerhaave, since it is in fact by an intestine movement

movement of which wine is fusceptible, that the acetous acid is fabricated; but feveral vegetable fubftances that are not vinous may form this acid, and it is not an indifpenfable condition of its exiftence that it fhall have been preceded by the vinous fermentation. In order to place whatever belongs to the hiftory of this fermentation in a more perfpicuous light, I fhall divide this article into fix paragraphs. The firft fhall treat of the conditions and the phe-phenomena of the acetous fermentation; the fecond, of feveral other means of obtaining acetous acid, different from that of fermentation, or of what I call in general *acetification*; the third, of the phyfical properties of vinegar, and of the acetous acid; the fourth, of its chemical properties; the fifth, of the different fpecies or modifications of the acetous acid, and efpecially of that which is called *acetic acid*; laftly, the fixth and concluding paragraph fhall defcribe the ufes for which vinegar, the acetous acid, and the acetic acid are employed.

SECTION I.

Of the Conditions, and of the Phenomena of the Vinous Fermentation.

2. THOUGH many vegetable fubftances, efpecially the leaves immerfed in water, farinas diluted with it, and the mucilages prepared from them

them with hot water, are capable of experiencing a ſpontaneous inteſtine motion which converts them into acid, it is more particularly upon wine that this kind of fermentation is practiſed, and has been well obſerved. There are three conditions eſſential to a vinous liquor, in order that it may paſs into the acetous fermentation. In the firſt place, it muſt be expoſed to a temperature from twenty to twenty-five degrees of Reaumur's thermometer. It is known that wines depoſited in vaults, the temperature of which is pretty conſtantly at ten degrees, remain without alteration. Secondly, it is neceſſary that they ſhould contain a certain quantity of mucilage and of tartar. On this account the wines ought not to be fined with iſinglaſs till the moment of bottling them. They are made to ferment much more quickly, eſpecially thoſe which are very generous, and yield much alcohol in diſtillation, by adding any kind of mucilage to them; ſugar even in ſmall proportion, but eſpecially melaſſes, ſerve alſo as a ferment. Thirdly, it is neceſſary that the wines ſhould enjoy the contact of the air; the more this contact is multiplied, the more quickly does the acetous fermentation eſtabliſh itſelf; a ſmall quantity of wine remaining at the bottom of a bottle paſſes quickly into the ſtate of vinegar, on account of the large volume of air which touches it in every part; and Rozier has found that a bladder filled with air attached to the bung-hole of a caſk of wine that was turning

ing four, was emptied by the abſorption of the air which it contained.

3. All wines are ſuſceptible of undergoing the acetous fermentation; but though thoſe of inferior quality are more particularly allotted to this purpoſe, the experiments of Becher, ſince repeated by Cartheuſer, prove that the ſtrong wines, which yield much alcohol by diſtillation, afford the beſt vinegar. Thus the wines of the country about Orleans, that are of good quality and ſufficiently generous, afford a vinegar which is in high eſtimation; in this manner alſo the quality of the vinegar prepared with weak wines is improved, by adding a little brandy to them previous to their fermentation. For the reſt, though the chemiſts have long conſidered vinegar on this account as a *ſpirituous acid*, we ſhall ſee hereafter that this property is relative only to the ſmell and taſte of the vinegar employed in the ordinary uſes of life, but by no means to its proper acid nature, which is independent of the preſence, or the direct proportion of the alcohol that may be united with it.

4. Whilſt the wine undergoes the acetous fermentation, a very ſenſible ebullition and hiſſing are perceived in the liquor; it becomes heated and turbid; it preſents many filaments and bubbles, which traverſe it in all directions; it exhales a lively acid ſmell, without diſengaging carbonic acid, as is the caſe in the vinous fermentation. Gradually theſe phenomena abate, the

the heat diminifhes, the commotion fubfides, the liquor becomes clear, after having depofited a fediment in reddifh glutinous flakes, which attach themfelves to the fides of the veffels. The wine is afterwards difpofed to undergo, provided all the circumftances favour it, a new and laft fermentation which would change its nature, and intirely decompofe it; and it ought not to be forgotten that fuch a difpofition actually exifts, and that precautions muft be taken againft the procefs of decompofition if we wifh to preferve it.

5. According to the conditions and the phenomena that have been indicated, it is not difficult to convert wine into vinegar; time alone effects this change in ill-clofed veffels that are expofed in places fufficiently warm. Thus, in many families, a barrel filled with wine already tending to acefcence is placed in a lower room kept conftantly at the temperature favourable to acetification. When it has intirely turned four, in fifteen or twenty days, a fmall quantity is drawn off for domeftic purpofes, by means of a cock placed towards the bottom, and the barrel is fimply filled up with an equal quantity of wine; by this means the wine that has been added paffes fpeedily into the ftate of vinegar, fo that this barrel, when once prepared as I have faid, fuffices for the fupply of the whole eftablifhment without a new fabrication being required, fince it is only neceffary to replace the vinegar that has been drawn off

off with an equal quantity of wine. We see here that the vinegar already formed serves as a ferment to the wine which is added. When it is necessary from any circumstance to recommence the operation, and when it is required again to make a barrel of vinegar for the first time, we throw into the wine that is put into the barrel that skin, or kind of membrane, which is taken out of barrels that have contained vinegar for a long time, and which is called *mother of vinegar*. This is a mucous, concrete deposition, proceeding from the gradual decomposition of the vinegar, and serves as a ferment to give rise to the acid fermentation in the other wine. This fact is so well known, that in neighbouring families this *mother of vinegar* is borrowed in the same manner as the leaven of bread.

6. Boerhaave has given, in his Elements of Chemistry, a very good process for making vinegar, which is still practised in many places. Two vessels are taken, in which is fixed at some distance from their bottom, an hurdle of osier, upon which vine branches and stalks are spread out: wine is poured into them, so as to fill the one completely, the other only half. The fermentation commences in the latter. When it is well established, this vessel is filled from the wine contained in the first. By this means the fermentation abates, in the full vessel, and commences in that which is half empty. When it has arrived at a considerable degree, the latter vessel is again filled with

with the liquor of that which had fermented the first; so that the fermentation, which follows the inverse proportion of the masses, recommences in this and abates in the other. The two vessels are thus alternately filled and emptied, till the vinegar is entirely formed, which generally requires from twelve to fifteen days.

Section II.

Of other Processes by which acetous Acid is obtained.

7. The acetous acid differs from the product of the vinous fermentation in the circumstance that it may be formed without this fermentation, that frequently it is the consequence of alterations, or of changes independent of the acid fermentation. The processes of the acetification, or of the conversion of the insipid, saccharine, mucous, extractive vegetable matters into real acetous acid, are very numerous; and there have been observed, especially for fifteen years past, a multitude of different circumstances in which those matters become acidified without experiencing any thing really similar to a fermentation.

8. These insipid, or sapid, but not acid matters, become so, and all become partly converted into the state of acetous acid, by the spontaneous action which the sulphuric acid exerts upon them. I have already several times observed, that the mere

mere tendency of the concentrated ſulphuric acid to ſaturate itſelf with water, is a very potent cauſe of alteration which it cauſes the vegetable matters to undergo. This alteration conſiſts in three diſtinct though ſimultaneous effects; firſt, a portion of the hidrogen of theſe matters unites with a portion of oxigen alſo belonging to them, to form water which ſaturates the acid; ſecondly, carbon is ſeparated, which renders the mixture brown and even black, and is ſoon precipitated to the bottom of the acid: at the ſame time that a third portion of theſe matters paſſes into the ſtate of acetous acid, which remains confounded with the ſulphuric acid, and may be ſeparated from it by diſtillation; ſo that there is no vegetable ſubſtance which, after having been treated in the cold by this powerful acid, does not yield more or leſs acetous acid, when afterwards ſubjected to the action of the fire.

9. The nitric acid which, as I have elſewhere ſhown, has a very active tendency to deſtroy the vegetable compounds, forms in them always a ſmall quantity of acetous acid, and at the ſame time the mucous and oxalic acids, and perhaps even malic acid. It has been ſeen that alcohol itſelf is in part converted into acetous acid, when treated by the acid of nitre. The muriatic acid alſo effects a ſimilar converſion when left for a long time with vegetable ſubſtances, though it is much leſs powerful than the ſulphuric and nitric acid. But it is moſt eſpecially

cially the oxigenated muriatic acid which, notwithſtanding its little ſolubility, when received in the ſtate of gas into the vegetable liquids or the ſolutions of vegetable matters, has the property of converting part of them into acetous acid. Thus when alcohol is treated with this agent it is converted much more into acetous acid than into ether, and it is on this account that the muriatic ether is always acid and little abundant.

10. It is not yet ſo well proved as has been thought, that moſt of the other vegetable acids are ſuſceptible of paſſing into the ſtate of acetous acid, and that this acid is the common term of their acidification. Though the tartarous acid appears actually to paſs into this ſtate, as well as the malic acid, and though from the conſtant preſence of the tartarous acidule in wine, it may be regarded as a ferment that promotes its acetification, and as furniſhing a ſubſtance which of itſelf becomes acetified, it ſeems that we cannot affirm the ſame of the oxalic acid, the ſtrongeſt and the moſt unalterable of the vegetable acids, which reſiſts all ſpontaneous alteration, in the ſame circumſtances in which the tartarous acid and the tartrites are decompoſed and deſtroyed.

11. We have juſt ſeen that acetous acid is formed in circumſtances different from fermentation, and that its production does not neceſſarily require the exiſtence of an inteſtine fermentative motion; there is alſo an acetous fermentation, whereby acetous acid is produced,

 without

without its having been preceded by the vinous fermentation, the previous existence of which was admitted after Boerhaave as indispensible; so that the name of vinegar ought now to be applied only to the wine itself become acid or sour, and that of acetous acid, which must present a more general idea than the word *vinegar*, substituted instead of it. Almost all vegetables are susceptible of passing actually into the acid or acetous fermentation, of yielding real acetous acid, without having previously undergone the vinous fermentation, without having first formed wine. This is what happens with leaves and roots, with cabbage that has turned sour in water, with *sour crout*, which has been so improperly called in French *choux croute;* starch or flour steeped in water, and forming the *sour water of the starch-makers*; dough itself, which, when it is suffered to rise a little too strongly, becomes sour, and gives a very perceptible taste to the bread that is produced from it.

12. It was formerly believed that, even in the cases which I have just mentioned, an insensible vinous fermentation first took place, and that all the vegetable substances that turned sour commenced with being in a vinous state; but we here manifestly discern the influence of a prejudice which, after the theory of Boerhaave, forced nature, as it were, to adapt itself to the ideas that had been formed. We cannot admit a vinous fermentation, of which we have no proof and no indication, in the sap of the

trees at the moment when it has just been extracted, in extracts rapidly prepared, all of which contain acetous acid. The human urine and that of the animals assuredly do not experience a vinous fermentation, and yet they easily yield this same acid by an intestine change of their own matter: we may therefore conclude that there exists an acetous fermentation independent of the vinous, that it is not its necessary consequence, and a formation of acetous acid in matters which are not in the vinous state.

Section III.

Of the Properties of Vinegar.

13. VINEGAR, or that impure kind of acetous acid, which is most constantly prepared and used, and which is made by the acetous fermentation of wine, is a reddish or yellowish liquor, called *white wine vinegar*, when of the latter colour, of a sour, pungent taste, which is pretty strong and agreeable, of a slightly aromatic smell, and retaining a portion of the alcohol of the wine not decomposed. It weighs from 10,135 to 10,251; water being 10,000. It varies much in its properties, accordingly as it is obtained from a wine more or less spirituous, coloured, strong, and generous, or weak and of bad quality. I do not here even speak of that to which sulphuric or

 nitric

nitric acid has been added, in order to give it more acidity.

14. This common liquor contains, befides the acetous acid, properly fo called, a certain quantity of tartar, which it does not depofit as wine does, a colouring extractive matter, fometimes even a little mucilage, and frequently a portion of the malic and citric acids. We likewife find in it fulphate of pot-afh, and even a little fulphate of lime. It may be fuppofed, however, that all thefe properties vary according to the nature of the wine from which it is obtained, and that therefore no two quantities of vinegar are perfectly alike. Accordingly the combinations of this acid are not what are ufually examined by chemifts.

15. Vinegar contains or nourifhes a fpecies of microfcopic animals, which have been very improperly termed *eels*, and are of the kind called animalcules of infufion. Modern naturalifts have given this fpecies the name of *vibrio aceti.* It exhibits a much more confiderable quantity of them when it begins to change, and it is very fufceptible of alteration. We fee it become turbid, much flocculent fediment fubfides in it, it acquires a mouldy fmell, and even forms a mucous and glutinous mafs, refembling what is called mother of vinegar. It is well known that it undergoes this decompofition much more fpeedily when it is left upon its lees, for which reafon it is racked off immediately after it is made. It appears, that tartar is

 one

one of the fubftances contained in vinegar, which contributes moft to its fpontaneous alteration; for the phenomena that take place in this decompofition are the fame as thofe in a folution of tartar.

16. When vinegar is expofed to froft, there is only a portion of it freezes: the frozen part is little more than water, and the part not frozen is ftrong vinegar. If this congelation be repeated, gradually increafing the intenfity of the cold each time, very little unfrozen vinegar will be obtained: this is very ftrong, lefs coloured, lefs liable to change, aud much more eafy to keep: it is called *vinegar concentrated by froft*. This is one mode of keeping it; but it is very expenfive, becaufe little is left that does not freeze. Scheele has difcovered a much better procefs for rendering it capable of being kept: this confifts in boiling it for a few minutes. After this operation, vinegar is much lefs liable to alter, and may be kept even in open veffels without fpoiling: it is evidently very fimple, and very applicable to domeftic purpofes.

17. The action of fire on vinegar is employed to obtain pure acetous acid. For this purpofe it is diftilled in a ftone cucurbit with a glafs head, or in a glafs retort placed in a fand-heat, with a receiver adapted to it. It muft be heated flowly, and only fo as to make the vinegar boil gently At firft a liquor of a quick, fragrant, aromatic fmell, paffes over, the firft portion of which is alcohol

alcohol mixed with a little acetous acid. To this ſoon ſucceeds a very pale acid liquor, of a ſtrong acid ſmell, which is the acetous acid, or diſtilled vinegar. As the diſtillation proceeds, the more acid it becomes, having leſs ſmell with more acidity: all theſe products may be obtained ſeparately, by changing the receiver at each; but this is ſeldom done. When the operator has drawn off about two-thirds of the liquor he expoſed to diſtillation, he puts an end to the proceſs: if more be drawn off, it will have an empyreumatic ſmell. After this product is obtained, what remains of the vinegar is a thick liquor, of a deep and dirty red colour; it depoſits a certain quantity of acidulous tartrite of pot-aſh; it is ſtill very ſour: it contains therefore acids more fixed than the acetous, which occaſions the acrid and empyreumatic ſmell ariſing from burned vinegar. This extract, diſtilled in a retort, yields ſome coloured acid water, brown oil, and a little ammonia, leaving behind a coal which contains a great quantity of pot-aſh.

SECTION IV.

Of the Chemical Properties of Acetous Acid.

18. I HAVE aſſerted, that chemiſts did not examine the properties of vinegar in its common ſtate; that, to diſcover the character of the acetous

acetous acid, they make uſe of that which they have extracted from vinegar by diſtillation: accordingly the combinations I am proceeding to examine, are thoſe of this pure acid. The acetous acid in this ſtate, poſſeſſing perfect tranſparency, of a ſufficiently agreeable ſmell, of a pungent ſour taſte, of a ſpecific gravity ſenſibly leſs than that of vinegar, ſince it reaches only 10,005, reddening blue vegetable colours, if expoſed alone to heat is volatilized, and evaporated intirely. It is more volatile than decompoſable: it keeps without alteration in cloſe veſſels: it does not act on hidrogen, carbon, phoſphorus, nor ſulphur: it unites with water in any proportion. We are not yet well acquainted with the manner in which it is affected by the powerful acids, though we know that concentrated ſulphuric acid, carbon, and nitric acid, decompoſe it into carbonic acid and water. It weakly diſſolves boracic acid, and abſorbs carbonic acid.

19. The acetous acid unites with all the earthy and alkaline baſes, and the ſalts it forms are characterized by their great ſolubility, their decompoſition by fire which converts them into coal, the ſpontaneous alteration of their ſolutions, and their decompoſition by a great number of acids, which diſengage from them the acetous acid in a very concentrated ſtate.

The following are the characteriſtic properties of the principal ſpecies of acetites hitherto examined.

amined. The order in which they are arranged, founded on the affinities of the acetous acid, is the ſame with that obſerved in a great number of foſſil ſalts.

A. The acetite of barites cryſtallizes in needles; its taſte is bitter; it effloreſces in the open air; it is very ſoluble; it is decompoſable only by the alkaline carbonates, and not by the pure alkalis or earths. It may be employed to detect the preſence and quantity of ſulphuric acid in vinegar ſophiſticated by this addition.

B. The acetite of pot-aſh exiſts in ſeveral vegetable juices; it has been ſeen, that all the extracts contain it; Citizen Vauquelin has found it in dunghills, and in mould; it has been diſcovered in ſaps; it is even ſeparated from the urine of ſome quadrupeds. It is prepared for pharmaceutical purpoſes; and was long called *foliated earth of tartar*, becauſe it was obtained in a dry foliaceous and not cryſtalline form. The preparation of this ſalt, which is much uſed in phyſic, conſiſts in ſaturating carbonate of the pot-aſh with acetous acid added to it in exceſs, filtrating the liquor, evaporating it over a gentle fire in a porcelain or ſilver veſſel, finiſhing the evaporation to dryneſs when the liquor is become thick, on a water-bath, or on hot aſhes. By theſe means a white ſalt is obtained: but if the evaporations were conducted over a ſtrong fire, the ſalt would become grey or brown, becauſe a part of the vinegar would burn.

The

The acetite of pot-aſh has a pungent acid taſte, becoming urinous and alkaline as it goes off. In the fire it melts, ſwells, decompoſes, and burns to a coal. Diſtilled in a retort, it yields ſome acid water, an empyreumatic oil, a little ammonia, and much carbonated hidrogen gas and carbonic acid gas. The coal which remains after this diſtillation contains pot-aſh uncombined, and frequently it is in the pyrophoric ſtate.

The acetite of pot-aſh ſtrongly attracts the moiſture of the air: it is extremely ſoluble in water, and produces cold as it diſſolves: its concentrated ſolution affords, though with difficulty, regular priſmatic cryſtals, but they are of very little permanence, on account of their deliqueſcency. The ſame ſolution, a little more diluted in water, is decompoſed ſpontaneouſly in cloſe veſſels: it depoſits a thick flocculent mucus, of a grey colour, and at laſt black; and at the end of a few months contains only carbonate of pot-aſh, ſoiled with a little carbonaceous oil. In this property it reſembles tartrite of pot-aſh.

The acetite of pot-aſh is decompoſable by the powerful acids. Diſtilled with concentrated ſulphuric acid, it yields an extremely acrid acetous acid, which, on account of its ſmell, has even been confounded with the acetic acid, of which I ſhall ſpeak hereafter. The tartarous and oxalic acids likewiſe decompoſe the acetite of pot-aſh, and they are ſtronger than the acetous

tous acid. We ſhall ſee further on, that this ſalt precipitates ſeveral metallic ſolutions by the help of the double affinities. When it is diſtilled with arſenious acid, or white oxide of arſenic, it yields a volatile, fuming product, of a horribly fetid ſmell, and which takes fire ſpontaneouſly in the open air, giving out a copious ſmoke and a reddiſh flame.

C. The acetite of ſoda has been very improperly named *mineral foliated earth*, ſince this denomination ought not to have been given, even in the ancient nomenclature, to a very cryſtallizable ſalt. It is prepared by ſaturating carbonate of ſoda with acetous acid. The filtered ſolution is evaporated to a ſlight pellicle, and on refrigeration it forms ſtriated priſmatic cryſtals, ſomewhat like thoſe of ſulphate of ſoda depoſited rapidly. This ſalt is bitter, pungent, and mixed with a taſte at firſt acid, afterward alkaline. It is decompoſed in the fire, like the preceding, and ſpontaneouſly in its aqueous ſolution. It is not like it, deliqueſcent: it leaves however a pyrophoric reſiduum after diſtillation. It is decompoſable by barites and pot-aſh.

D. We are yet very little acquainted with the acetite of ſtrontian: we know only that this combination has a ſweet taſte, that it is very ſoluble, and that it is eaſily decompoſed by a ſtrong heat.

E. The acetous acid combines eaſily and readily with lime: it diſſolves the carbonate of lime with effervescence: when it is saturated with it, and when the solution is evaporated to a pellicle, it yields crystals in very fine prisms, in a sort of shining satin-like needles. This salt is acid and bitter: it effloresces in the air, like the acetite of barites: it is decomposed by this base, as well as by the two fixed alkalis. The powerful acids expel the acetous from it with effervescence, as from all the other acetites. It decomposes several salts by double affinity. The acetite of lime is frequently obtained in chemical analysis, on treating with acetous acid the residuums of mineral waters, and different earths or stones divided by fusion with pot-ash.

F. The acetous acid unites readily with ammonia: this fluid combination, with excess of acetous acid, forms the *spirit of mindererus* prepared in the shops. It is the ammoniacal acetite. On evaporating it, to endeavour to obtain crystals, it volatilizes intirely: hence some chemists have proposed to prepare it by distillation. It is thus that it is extracted from dunghill waters, from some fermented saps, and even from altered wines. Some have affirmed, however, that they have obtained a few needled crystals of it, of a warm pungent taste, and very deliquescent. This salt is decomposed by fire, by the acids, by the alkalis, and by several earthy bases; it undergoes spontaneous destruction.

G. The acetite of magnesia is very easily prepared by the direct union of acetous acid with

carbonate

carbonate of magnefia, which it diffolves with effervefcence. It cryftallizes but very difficultly, and its folution yields when evaporated, a vifcous, deliquefcent mafs. By this property it is eafily feparated from the acetite of lime, with which it is frequently confounded in the dry form, in the product of the evaporation of the earthy refiduums of mineral waters treated by acetous acid. This faline mafs, always fatiny and fhining, attracts moifture, and diffolves in the open air. As long as it contains any acetite of magnefia, this is gradually feparated as it liquefies; and when no farther deliquefcence takes place, the remainder is pure acetite of lime.

The acetite of magnefia, befides the generic properties of the acetites, is decompofable by barites, the fixed alkalis, ftrontian, lime, and partly by ammonia.

H. The acetous acid diffolves glucine very well. This folution, according to Citizen Vauquelin, does not cryftallize: it is reduced by evaporation to a gummy fubftance as it were, which flowly dries and becomes brittle, but long retains a fort of ductility. Its tafte is faccharine, and pretty ftrongly aftringent; yet it permits us to diftinguifh that of vinegar.

I. This acid diffolves alumine very difficultly: it forms with it little needly cryftals, foft, fenfibly aftringent, and decompofable by all the preceding bafes. We yet know little of the properties of acetite of alumine.

K. It

K. It is the fame with the acetite of zircon. It has been very little examined hitherto: all that we know is, that this faline combination exifts; and that it is gelatinous, and decompofable by all the alkaline and earthy bafes with which we are acquainted.

20. The acetous acid acts on a great number of metallic fubftances, and in its combination with thefe exhibits phenomena more or lefs important for us to know, or compounds more or lefs ufeful.

21. It has no action on arfenic, and does not diffolve the arfenious acid: yet this acid, being diftilled with an equal quantity of acetite of pot-afh, afforded Citizen Cadet and the chemifts of the academy of Dijon, a red, fuming liquor, of a very noifome fmell, very tenacious, and of a very fingular nature. Citizen Cadet had already obferved, that this liquor was capable of inflaming fat lute. The academicians of Dijon, defirous of examining the yellowifh matter of an oily confiftence, collected at the bottom of the veffel that contained the fuming arfenico-acetous liquor, decanted a portion of the fupernatant fluid, and poured the reft on a paper filtre. Scarcely had a few drops paffed through, when on a fudden arofe a very denfe noifome vapour, which formed a column from the veffel to the cieling; a kind of ebullition took place about the edges of the matter, and a fine rofe-coloured flame iffued from it, which continued a few inftants. This liquor, which the

chemifts

chemists of Dijon compared to a liquid phosphorus, is a sort of pyrophorus like those which will be mentioned hereafter. The residuum of the distillation of the acetite of pot-ash with arsenious acid consists of pot-ash chiefly.

22. The acetous acid dissolves cobalt in the state of oxide, and forms a solution of a pale rose colour, which yields no crystals, but the properties of which are not known.

23. It has no action on bismuth, or on its oxide, but it dissolves the oxide of manganese. We know nothing of its action on titanium, uranium, tungsten, molybdena, or chrome.

24. According to Arwidson, it dissolves nickel directly: this solution affords green crystals, in figure resembling a spatula.

25. This acid does not act on antimony; but it appears to dissolve the vitreous oxide of this metal, since Angelus Sala made an emetic preparation with these two substances.

Its action on tellurium is unknown.

26. Zinc, as well as its oxide, dissolves very readily in acetous acid. Citizen Monnet has obtained crystals in flat laminæ from this solution by evaporating it. The acetite of zinc fulminates on burning coals, and gives a small blueish flame after melting and swelling up. By distillation it yields an inflammable liquor, a yellowish oily fluid, which soon becomes of a deep green, and a white sublimate, which burns in the flame of a candle with a fine blue colour. The residuum is in the state of a pyrophorus but little

little combuftible. Hence we fee vinegar muft diffolve the kind of tinning made with zinc. Dr. Laplanche has proved, that the acetite of zinc is not dangerous to the animal economy.

27. Acetous acid does not diffolve quickfilver in the metallic ftate. This combination however is effected by agitating it ftrongly by means of whifks or agitators, as Keyfer did. In this operation the quickfilver is firft converted into black oxide, and afterward diffolved in the acid.

Quickfilver in the ftate of oxide is eafily united with the acetous acid. It is fufficient to boil this acid on the red oxide of mercury, called precipitate *per fe*, or turbith mineral, or on mercury precipitated from its nitric folution by pot-afh. The liquor becomes white, and grows clear when it boils; it is then to be filtered: on refrigeration filvery cryftals are precipitated from it in little fpangles, or in ftriated laminæ fimilar to the boracic acid. This acetite of quickfilver has been called foliated earth of mercury. It is prepared extemporaneoufly by pouring a nitric folution of quickfilver into a folution of acetite of pot-afh: the nitric acid unites with the fixed alkali of the latter falt, forming with it nitre, which remains diffolved in the liquor; and the oxide of mercury, combined with the acid of vinegar, precipitates at firft in a yellowifh white powder, and afterwards in the form of fhining fpangles, particularly if the liquor be evaporated. The mixture being filtered, the acetite of mercury remains on the filter. This falt is decom-

pofed

posed by the action of fire: its residuum yields a sort of pyrophorus. It is easily altered by combustible vapours; is acrid, and is not very safe as a medicine.

28. Tin is little altered by the acetous acid. This acid dissolves but a small quantity of it, and the solution, when evaporated, yields according to Citizen Monnet a yellowish crust, similar to a gum, and of a fetid smell.

29. Lead is one of the metals on which the acetous acid has most action. This acid oxides it, and dissolves its oxides with the greatest facility. On exposing sheets of this metal to the vapour of warm vinegar, they become covered with a white powder, called *ceruse*, which is nothing but an oxide of lead containing a little vinegar. This oxide, ground with a third part of chalk, forms *white lead*. To saturate vinegar with all the oxide of lead it can dissolve, this acid is poured on ceruse in a matrass: the mixture is digested in a sand-heat: the liquor is filtered, after it has stood in digestion some hours: it is then evaporated to a pellicle: and it furnishes, by refrigeration and repose, white crystals, which are shapeless needles, if the liquor were too much concentrated, and flattened parallelopipeds, terminated by two bevilled surfaces, if the evaporation were properly conducted. This acetite of lead has been called *salt* or *sugar of saturn* on account of its saccharine taste, which is at the same time slightly styptic.

A similar

A ſimilar ſalt is prepared with the vitreous oxide of lead, or litharge, and vinegar. Equal parts of theſe two ſubſtances are boiled together to ſaturation; evaporated to the conſiſtence of a thin ſyrup; and we have then *Goulard's extract of ſaturn*, known long before his time by the name of vinegar of ſaturn.

The acetite of lead is decompoſed by heat: on diſtillation it affords an acid, red, very fetid liquor, differing greatly from the acetic acid, which will be mentioned preſently. The reſiduum of the diſtillation is a very good pyrophorus. This ſalt is decompoſed by diſtilled water, by lime, the alkalis, and the acids with ſimple radicals, as well as by ſeveral vegetables, which yield with it inſoluble ſalts; and mixed with a little brandy it forms the vegeto-mineral water.

30. The acetous acid diſſolves iron with activity. The effervеſcence that takes place in this ſolution is owing to the diſengagement of hidrogen gas furniſhed by the water, which is decompoſed. The liquor aſſumes a red or brown colour. By evaporation it yields only a gelatinous magma, mixed with ſome brown elongated cryſtals. The acetite of iron has a ſtyptic and ſweetiſh taſte: it is decompoſed by heat, and lets its acid eſcape: it attracts the moiſture of the air: it is decompoſed in a large quantity of diſtilled water. When it is heated till it yields no more ſmell of vinegar, it leaves a yellowiſh oxide, eaſily reducible, and attracted by the magnet. The acetous ſolution of iron yields a very black ink

with galls, and may be employed with fuccefs in dyeing: alkaline pruffiates precipitate from it a very brilliant Pruffian blue: pure alkalis, in particular ammonia, feparate the iron from it in the ftate of an oxide almoft black, and this precipitation has been propofed for preparing the *martial ethiops*. The black, yellow, and brown oxides of iron, and the native carbonate of iron, or fparry iron ore, afford very fine red folutions with acetous acid.

31. Copper is oxided and diffolved with great facility in the acetous acid. The folution of this metal, affifted by heat, gradually affumes a green colour: but this is more eafily produced with the metal already altered and oxided by vinegar. Copper thus oxided, is the *verdet gris*, or verdigris. It is prepared in the neighbourhood of Montpelier by putting fheets of thin metal into earthen pots with grape ftalks, which had been previoufly wetted and fet to ferment with the refiduum left after diftilling brandy from wine. The furface of thefe fheets is foon covered with a green ruft, which is increafed by placing them in heaps, and fprinkling them with vinegar: the copper is then fcraped, and the verdigris is packed up in fkin bags as an article of trade. Montet, an apothecary at Montpelier, has very well defcribed this manufacture in two Memoirs printed among thofe of the Academy of Sciences in 1750 and 1753.

Citizen Chaptal has made known to the Inftitute the improved proceffes at prefent employed

ployed for this preparation. It has been remarked that the acetite of copper was formerly prepared with dried grape-ſtalks, which were ſoaked for a week in the liquor left after diſtilling brandy from wine, and afterward ſet to drain in a baſket: theſe were put into an earthen pot, called an *oule*, and four litres of wine were poured in, with which the ſtalks were well impregnated by ſtirring and ſqueezing them with the hand in the liquor: as ſoon as the fermentation and heat ſubſided, the ſtalks were taken out, and laid in layers with the ſheets of copper.

At preſent we take the grapes from which the juice has been preſſed; put them into a caſk, raiſing them up and giving them air; ſet them to ferment; and place them with ſheets of copper, ſtratum ſuper ſtratum, in earthen pots or *oules* made for this purpoſe. In ten or fifteen days the copper ſheets will be covered with little ſilky cryſtals; and then they are placed edgewiſe on rods arranged for the purpoſe in a corner of the manufactory. After remaining thus three or four days, they are dipped in water, and replaced on the rods. This immerſion and deſſiccation are repeated once a week for near two months: and then the coat of verdigris, that covers both ſides of each ſheet of copper, is ſcraped off with a wooden knife. It is obvious, that this latter proceſs which is generally adopted, has every advantage: inſtead of conſuming a large quantity of wine like the former, it requires only a product of no value.

Verdigris diffolves fpeedily in acetous acid. This folution, which is of a fine greenifh-blue colour, furnifhes by evaporation and refrigeration deep blue cryftals in truncated quadrangular pyramids, to which have been given the name of *verdet*, or *cryftals of Venus*. Thofe that are prepared as an article of trade, and called diftilled verdigris, becaufe they are made with diftilled vinegar, are in the form of a beautiful pyramid : the cryftals arranging themfelves in this manner, becaufe they are depofited on a ftick cleft in four at one end, and the parts kept feparate by a bit of cork. Citizen Chaptal recommends it to be prepared by mixing a folution of fulphate of copper with a folution of acetite of lead; when a fulphate of lead would be precipitated, which might be ufed for white lead, and the fupernatant liquor would contain acetite of copper, which might be obtained by evaporation.

This falt has a ftrong tafte, and is very poifonous. It is efflorefcent, very foluble, and decompofable by all the alkalis. Expofed to the fire, and by diftillation, it gives out its acid in a peculiar ftate, which will be mentioned farther on.

32. The acetous acid diffolves oxide of filver, of gold, and of platina, particularly by the affiftance of heat. Thefe acrid and cauftic folutions are decompofed by fire, by alkalis, by the hidro-fulphurets, and hidrogenized fulphurets. Bergman has remarked, that this acetous folution of

of gold produces fulminating gold with ammonia. For the reſt, this acid has no action on theſe three metals, the leaſt oxidable of any known, whatever the alchemiſts have ſaid.

33. Vinegar is capable of uniting with many of the immediate materials of vegetables. It diſſolves the extracts, mucilages, and eſſential ſalts: it even acts a little on the gum-reſins and oils: it is eaſily united with the extractive and colouring matters of vegetables, ſo as to acquire their taſte, ſmell, and medicinal or agreeable properties. On this is founded the art of making medicinal vinegars, vinegars for the table and the toilet, and aromatic vinegars, by ſimple infuſion or diſtillation: the pretence formerly held out of fabricating very important medicinal vinegars by fermenting medicinal herbs with wine has long been exploded as an error.

Vinegar likewiſe diſſolves very readily the gluten of wheaten flour; and we may ſeparate this ſubſtance, with its elaſticity and characteriſtic properties, from this ſolution, even after it has been kept ſeveral years, by means of alkalis.

SECTION

SECTION V.

Of the different Modifications or Species of Acids afforded by Vinegar.

34. IT has been seen by the detail of the properties hitherto described, that the acid of vinegar is liable to be found in certain peculiar modifications, and that it might be distinguished in each of these, if not as a separate species, yet as a variety deserving a special and determinate denomination. Thus to the word vinegar we add those of *concentrated by frost*, to distinguish that which has been deprived of part of its water by congelation; and the word *boiled*, to indicate that conservatory effect, which a few minutes of ebullition produce in it. Thus also the expression of *acetous acid*, *synonimous* with that of *distilled vinegar*, distinguishes and sufficiently characterizes its nature, so as to leave no room for mistake respecting them.

35. No doubt fresh observations, made with much care, will hereafter lead us to consider as a particular variety of this acid that which is obtained by the distillation of earthy or alkaline acetites, and that which is expelled by heat from the acetite of lead. But of all the modifications of this acid, that which has been hitherto most carefully distinguished, most studied, and has in fact

fact exhibited to the observer the most striking and remarkable differences, is the product of the decomposition of the crystallized acetite of copper by means of heat.

36. When this salt reduced to powder is distilled in a glass or earthen retort with a receiver, a fluid is obtained, at first clear and of little acidity, but which soon acquires a considerable degree, insomuch that it seems to equal the concentration of the mineral acids. The receiver is changed, in order to have these two products separate; the latter of which has been called radical vinegar, or vinegar of Venus. This acid is coloured green by a certain quantity of oxide of copper, which it carries over with it in distillation. When nothing more comes over, and the retort is red-hot, the residuum this contains is in the form of a brown copper coloured powder, and often gives to the sides of the vessel the shining appearance of this metal. The residuum is strongly pyrophoric: it contains but little oxide, with a little charcoal.

The vinegar of Venus is rectified by distillation with a gentle heat. It is then perfectly pale and clear, if we take care that the fire be not too strong toward the end of the operation, and that the portion of oxide of copper, which remains in the retort, be not too much dried.

37. The reduction of the copper, observed in this experiment, elucidates the nature of the radical vinegar. It was formerly observed, that this acid is to common vinegar what the oxigenated muriatic

muriatic acid is to the pure muriatic, or rather what the ſulphuric acid is to the ſulphureous, and the nitric acid to the nitrous. In this operation, the acetous acid appeared to unite with the oxigen of the oxide of copper, which at the ſame time paſſed to the metallic ſtate. The effects produced by radical vinegar, differing conſiderably from thoſe of common vinegar, ſeemed therefore owing to the exceſs of oxigen, which this acid had acquired. Such was the theory adopted by Citizen Berthollet: and it was on this account that the acid was called acetic, conformably to the rules of nomenclature ſo often exhibited in this work.

But Citizen Perès, a druggiſt, firſt began publicly to expreſs doubts reſpecting the compound nature of this acid; and to affirm, both from ſeveral facts already known but more accurately compared by him, and from ſome experiments of his own, that the only difference exiſting between this acid and the acetous might very well be aſcribed to the proportion of carbon being leſs in the former, and greater in the latter.

At the end of the year 6, Citizen Adet read at the Inſtitute a Memoir on the difference of theſe two acids, in which he deſcribed ſeveral new experiments on the diſtillation and products of acetite of copper, on the treatment of the acetous acid by oxide of manganeſe, and on the combinations of the acetic acid compared with thoſe of the acetous. After having ſhown, that water

water and carbonic acid are formed, and that carbon is left bare, during the diſtillation of acetite of copper; that the acetous acid diſtilled upon oxide of manganeſe never becomes oxigenated; that the acetic acid united with metallic oxides does not comport itſelf differently from the acetous acid; that the acetic acid does not attack metals any more than the acetous; and that the ſalts formed by the two acids with earthy and alkaline baſes exhibit but very ſlight differences; he thought himſelf warranted to conclude from his labours: 1ſt, that the acid of vinegar abſorbs no oxigen in its combination with oxide of copper, and does not exhibit itſelf in two different ſtates: 2dly, that it is always in the higheſt degree of oxigenation, and always in the ſtate of acetic acid, even in that of diſtilled vinegar, hitherto called acetous acid: 3dly, that no acetous acid properly ſo called exiſts, unleſs we think fit to give this name to the tartarous and malic acids, which become acetic acid by the addition of oxigen: 4thly, that there exiſt no acetites, but only acetates: 5thly, and laſtly, that the difference between what have hitherto been called *acetous* acid and *acetic* acid appear to him to depend ſolely on the concentrated ſtate of the former, and its containing a much ſmaller quantity of water than the latter.

38. But this concluſion of Citizen Adet appears in truth a little forced, and not reſtricted with the preciſion expreſſed in the experiments preceding it. In fact, we cannot avoid perceiving differ-

ences

ences between the two acids announced in the experiments of Citizen Adet himſelf; particularly in their combinations: differences of which this chemiſt profeſſes that he ſhall endeavour to inveſtigate the cauſe.

Laſtly, Citizen Chaptal has employed himſelf on this ſubject; and about a month after the publication of Citizen Adet's labours, he communicated to the philomathic ſociety ſome obſervations and experiments, whence he conceived himſelf juſtified in drawing inferences ſomewhat different from thoſe of Citizen Adet. The acetous and acetic acids, previouſly reduced to the ſame degree of ſpecific gravity and concentration by means of water, preſented a great difference in ſmell and taſte: the acetic, which was much more acrid, formed a well cryſtallized ſalt with oxide of copper; the acetous became ſcarcely tinged, of a bluiſh-green, and afforded only a ſaline cruſt: the acetous required one ſixth leſs of pot-aſh to ſaturate it than the acetic. On diſtilling each with a fourth of its weight of ſulphuric acid, the mixture of acetous acid became coloured of a deep red, that of acetic of a ſtraw-colour; the acetous, leaving charcoal in the retort, came nearer to the acetic: the acetite and acetate of pot-aſh being both evaporated to dryneſs, and alike diſtilled by a fire, graduated ſo as to decompoſe them completely, the former left a thirteenth of its weight, the latter a ſeventeenth. On diſtilling the acetite of copper, a portion of the carbon of

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the acetous acid attacks the oxigen of the oxide of copper, and flies off in carbonic acid; another remains in its natural ſtate with the copper: thus the acetous acid paſſes to the acetic ſtate by loſing a part of its carbon, which the acids or metallic oxides ſeparate from it.

Citizen Chaptal concludes from theſe experiments, that the acetous and acetic acids really differ from each other, in the former containing more carbon than the latter; that the acetous acid becomes acetic only by parting with carbon; and that the modification depends only on the ſubtraction of carbon, or diminution of the radical, not on the addition of oxigen, or the augmentation of the acidifier, as takes place in acids with ſimple radicals.

In fact it is to be remarked here, that the binary hidro-carbonated radical of this acid muſt undergo a change, when the proportion of carbon in it is diminiſhed; that after this it no longer contains in reality the ſame radical; that conſequently it is not poſſible to make it again return to the ſtate of acetous acid; but that nevertheleſs the acid thus decarbonated may ſtill be conſidered as an acid more oxigenated than the acetous, ſince the proportion of the acidifier is in fact augmented by diminiſhing that of the carbon; and that therefore it ought to retain the appellation of acetic acid. We ſhall proceed to deſcribe its diſtinguiſhing properties.

39. The acetic acid well rectified is of ſuch a briſk and penetrating ſmell, that it is impoſſible

tizen Lauraguais. Yet many French chemifts have repeated the procefs; and I can affirm, that I have performed it myfelf with fuccefs, though it is true I obtained but a fmall quantity of ether, compared with what is formed by the powerful acids.

Citizen Laplanche, a druggift at Paris, prepares acetic ether by pouring concentrated fulphuric acid and alcohol on acetite of lead introduced into a retort. The theory and practice of this operation, are precifely the fame with thofe of the nitric and muriatic ethers prepared by a fimilar procefs.

The acetic ether has an agreeable fmell like all the other ethers, but the fmell of acetic acid may be diftinguifhed in it. It is very volatile and very inflammable: it burns with a vivid flame, and leaves a coally mark after combuftion.

41. The action which acetic acid exerts on the immediate materials of vegetables has not been appreciated in comparifon with that of the acetous: if it have any different effects, they are no doubt owing to its activity and energy. It has not yet been ufed for any purpofe in pharmacy or manufactures, fo that we are altogether ignorant whether it have any thing diftinct in its mode of action in thefe refpects.

SECTION

SECTION VI.

Of the Ufes of Acetous Acid.

42. EVERY one knows how much common vinegar is ufed for domeftic purpofes, and what important fervices it renders fociety: it is the moft frequent and ufeful condiment that can be employed: it is mixed and united with all kinds of food, the infipidity of which it conceals, or heightens their flavour. There are few perfons to whom it is not agreeable. It is drank mixed with water, and often in combination with fugar or honey. The Romans made their foldiers drink water acidulated with vinegar, *pofca*, and to this cuftom is afcribed the permanent healthinefs of their armies. Notwithftanding the benefits of vinegar, and its general ufe in feafoning, the abufe or excefs of it is injurious: it diforders the ftomach, and enfeebles it, diffolves and foftens the organic texture, and produces leannefs. It is ufed as a prefervative againft peftilential difeafes. It enables us likewife to keep fruits, certain leaves, and feveral alimentary fubftances, which are left to macerate in it a longer or fhorter time.

43. Phyficians have greatly multiplied the ufes of vinegar as a medicine: it is refrefhing,

cooling,

cooling, antiseptic, anti-bilious. A very agreeable syrup is made of it: it is combined with honey; and to this preparation, called *oxymel*, squills are added, and even colchicum, to render it diuretic, aperitive, incisive. Common vinegar is the vehicle of many medicaments: a great number of different plants are infused or macerated in it, to prepare the vinegar of squills and of meadow-saffron, aromatic, bitter, antiscorbutic, and theriacal vinegar, and that of the four thieves. It is distilled with very aromatic plants, to obtain odoriferous vinegars, intended chiefly for the toilet. The various common preparations designed for the table, made by infusions in vinegar, are well known; particularly elder vinegar, rose vinegar, tarragon vinegar, garlic vinegar, and all the varieties that have been invented, to multiply the flavours and smells of this liquid.

44. The acetous acid, or distilled vinegar, is employed in a great number of pharmaceutical combinations. As the acetites of pot-ash and soda, which are prescribed as attenuants in doses of a few grammes: the acetite of ammonia, which is administered as a cordial by the name of *spirit of Mindererus*: the acetite of quicksilver, called *foliated earth of mercury*, which forms the basis of Keyser's remedy for venereal diseases: the acetite of lead, frequently prescribed for external use in the medicaments, called *extract of saturn, salt,* or *vinegar of saturn, vegeto-mineral water, cerate of saturn,*

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but which ought to be employed with great prudence and moderation. The moſt ſkilful and judicious phyſicians alone have a right to preſcribe ſuch compoſitions, which may do much miſchief in the hands of men ignorant of their effects; and much more ought we to be afraid of employing ceruſe, verdigris, and the cryſtallized acetite of copper; ſubſtances which ſcarcely enter into any preparations, a few ointments for external uſe excepted.

45. Theſe oxides and metallic ſalts, prepared with lead and copper by means of vinegar, are uſed for a great many purpoſes in the arts. For painting in particular they are in great demand. It muſt not be forgotten, that by employing them in the arts we expoſe ourſelves to very ſerious dangers, and to be poiſoned, if we be not very attentive.

46. The acetic acid is uſed as an irritant, and a very active ſtimulus. It is held to the noſtrils of perſons who faint; for which purpoſe a ſmall quantity is commonly poured on ſulphate of pot-aſh in coarſe powder, and kept in a well-ſtopped bottle: this preparation is very improperly called *ſalt of vinegar*.

The acetic ether is begun to be employed in practice. Citizen Sedillot the younger ſays, he has uſed it with great ſucceſs in frictions, and even internally, in rheumatic pains and affections.

No other combination of the acetic acid is yet known or employed in the arts.

Article VI.

Of the Panary and Colouring Fermentations.

1. IN ſpeaking of the diſtinctions of the different ſpecies of fermentation, I have aſſerted, that the fermentation, which I call *colouring*, is a mean between the acid and putrid fermentations, and that it was neceſſary to ſtudy it along with theſe: I here add the panary fermentation, becauſe it would be of little uſe to make it the ſubject of a particular article, and becauſe it equally holds a mean between the putrid and the acid. Beſides, though we ſee plainly, that both theſe ſpontaneous movements are really placed between theſe two fermentations, they are yet too little known, too little ſtudied, to be treated ſeparately, and to deſerve each a diſtinct article.

2. It requires but a ſimple and eaſy obſervation of dough of wheaten flour, expoſed to a temperature from fifteen to eighteen degrees, after being mixed with a certain proportion of yeaſt or paſte already fermented, to ſatisfy ourſelves that it experiences in fact a real fermentation. This dough riſes, ſwells, increaſes in bulk, dilutes internally, ſeparates in ſome points, and becomes filled with cavities or eyes, manifeſtly produced by the extrication of an elaſtic fluid. At

At the ſame time it is obſerved to grow warm, it changes its colour, it does not retain its viſcous and adheſive conſiſtence; it acquires a ſmell ſomewhat pungent, and a taſte altogether different from the kind of inſipidity which it poſſeſſed before this movement. In theſe ſigns we cannot eaſily avoid diſcovering a true fermentation.

3. Attempts have been made to determine in what this fermentative motion of dough conſiſts; and to ſhow that it is not a particular fermentation, but merely the three fermentations ariſing ſimultaneouſly and reciprocally, confining the effects of each other to their commencement. According to this opinion, the feculent matter of the flour tends to grow ſour, while the ſaccharine mucous ſubſtance become viſcid, and the gluten putrifies. From theſe three movements coinciding, and mutually reſtricting each other, proceeds the mixed fermentation, which gives riſe to leavened dough, and produces light, delicate bread, agreeable to the taſte, and eaſy of digeſtion.

4. But this mode of viewing the ſubject is not yet ſupported by any ſubſtantial proofs. There is not enough ſaccharine matter in flour, and what is in it is not ſufficiently free, to produce the ſlighteſt movement of vinous fermentation: the fecula is neither ſufficiently at liberty, nor ſufficiently heated, to paſs into the ſtate of acetification in the ſhort ſpace during which the dough is riſing. We have nothing

left therefore but the glutinous matter, which is more abundant, more diluted, more raifed by the water it has abforbed; much more difpofed than the other component parts of the flour to undergo an inteftine movement, which divides, feparates, and rarefies the mafs; which parts it fo eafily into flakes by its fimple difpofition; which fills it, and forms the cavities fo well known in bread duly rifen, and properly baked; which tends fpeedily to decompofe it completely, almoft in the manner of animal fubftances. Though it is certain that it paffes through an acid ftage, when it is fuffered to go beyond the fimple rifing, which bread ought to have, it is equally fo, that it likewife tends readily to putrify.

5. Thus without having recourfe to the fimultaneoufnefs of three fermentations, we may admit one in the gluten of the flour, which fermentation is neither an acetification, nor a formation of wine, nor a putrefaction, but rather a commencement of putrid decompofition, which only divides the mafs, diminifhes, nay deftroys its vifcofity, extricates from it fome bubbles of elaftic fluids, modifies its tafte and fmell; in a word, changes its properties in a very remarkable manner. Unqueftionably it is not a fermentation completed, for then it would be a putrefaction: it is but a firft ftage of fermentation, which art checks, after having excited it, after having brought it to fuch a point, as to give the dough that degree of attenuation

and lightnefs, which was requifite to make good bread; for which reafon the name of *panary fermentation* has been given it: it is far from being terminated; it has fcarcely begun to act on the dough, and this has fcarcely begun to rife, when its progrefs is ftopped by the baking, to which the mafs is fubjected, in order to give it the tafte and defirable properties of bread.

6. It is the fame with the colouring fermentation, which is only carried a little further in the proceffes of art, than that which dough for bread is made to undergo. Like this, too, it is only a real decompofition more or lefs advanced toward putrefaction, a commencement of refolution, which tends to deftroy the vegetable matter completely. There is no perfon who has not obferved, that, in the courfe of this putrid decompofition, the vegetable fubftances that undergo it, affume in general a more or lefs decided colour. Thus fruits grow darker and brown, mufhrooms become black, mucilages change yellow and red; leaves immerfed in water feem at firft to acquire a deeper green, and afterward affume a brownnefs which approaches to black. Thus the whiteft vegetable falts, the tartrites and acetites, exhibit in their tranfparent folutions, yellow, brown, and blackifh clouds or flakes, the mucous products of their flow alteration, which at length depofit carbonaceous particles.

7. This confiderably accurate, though very general notion, ought to be applied to what paffes in the

the preparation of ſeveral colouring matters derived from vegetable ſubſtances, which are fermented in the preparation of weld or woad, and of indigo. This phenomenon is pretty accurately proved: the fine blue colouration, the formation of the moſt beautiful, moſt laſting, and moſt valuable colour, that the art of dyeing poſſeſſes, is the produce of a real fermentation: and ſince the plant alone immerſed in water undergoes, in order to aſſume this tint, an inteſtine motion of which there are indubitable ſigns in the increaſe of volume and temperature, the riſing of a ſcum, and a conſiderable noiſe, and the rather copious extrication of an elaſtic fluid mixed with carbonic acid and carbonated hidrogen gas; we cannot avoid acknowledging this fermentation to be the true ſource of the colouring matter formed, ſince this does not appear without unequivocal ſigns of the fermentation.

8. But is it a fact, as it has appeared to ſome modern writers, that this colouration is a particular fermentation, that it deſerves to be carefully diſtinguiſhed from all others, and even expreſſed by a ſpecial name, as I have done in this article, to ſtrike the attention of all who would ſtudy vegetable chemiſtry with care? I do not think, that in the preſent ſtate of our knowledge we can embrace ſuch an opinion. No doubt, from the peculiar product obtained, which is not leſs remarkable than uſeful, we may adopt the term of colouring fermentation, if

if we attach only this idea to it; but we ought not by this to underſtand, that it is a movement different from all others with which we are acquainted: we ſhould conceive it ſolely to indicate the peculiarity of the product.

9. The panary and colouring fermentations then are truly and eſſentially nothing but commencements of ſpontaneous decompoſition, which would quickly terminate in the putrefaction and complete diſſolution of the vegetable matters, if they were not ſtopped at a certain point, by ſubjecting the product of the former to that baking which converts it into bread; and by removing the divided and blue fecula of the other out of the liquor, in which it is proceeding toward putrefaction, and to dry it quickly. In the former, the dough is on the verge of acidity, when it is put into the oven: in the latter, a conſiderable quantity of carbonic acid and of ammonia is already formed at the expenſe of the plant, and if the production of either of theſe were to continue, a complete diſſolution of the vegetable would be the conſequence; but being ſtopped in due time, this decompoſition exhibits a matter already very carbonaceous, of which carbon conſtitutes the principle in exceſs, and renders its durability as a colouring ſubſtance ſo great, and its alteration ſo difficult.

Article VII.

Of the Putrid Fermentation.

1. PUTREFACTION is the laſt kind of fermentation I have diſtinguiſhed, and it is in fact that which terminates all the others, and effects the complete decompoſition of vegetables. No part of plants is exempt from this movement, and yet we may keep almoſt all free from it, by depriving them of water, the contact of air and heat. Some ancient chemiſts, Becher in particular, had eſtabliſhed a ſort of compariſon between putrefaction and combuſtion; and this idea, though it was difficult to prove it properly in remote times, was founded on an obſervation well made, and has been confirmed in our days.

2. For putrefaction to take place in vegetables many circumſtances are neceſſary. Their texture muſt be relaxed by water: all dry vegetable matters keep without alteration; on the contrary, all that are ſufficiently moiſtened rot. This happens to the hardeſt woods, the drieſt cords, the tougheſt ſtalks. The contact of air contributes greatly to produce and keep up this movement: we have a great number of facts of flowers and fruits being preſerved freſh and found in a vacuum, or in places well cloſed and ſecured from

from the contact of air. A high temperature is not necessary to keep up vegetable putrefaction: ten or fifteen degrees are sufficient, though a greater heat is not detrimental, but accelerates it; yet it must not be so great as to produce that dryness which is a preservative from it. Exsiccation in an oven is the most antiseptic process known for all vegetable substances whatever. Quantities of vegetables heaped together, but not compressed, singularly favour this spontaneous analysis.

3. All the conditions requisite to putrefaction being united, this decomposition announces itself by a change of colour and consistency in the parts of plants; their texture relaxes and softens; their laminæ, their fibres separate and rise up; their soft and fluid parts swell, and become covered with scum: elastic fluids distend them, traverse them, and escape from them: their temperature increases, and sometimes even so as to produce conflagration. The gases evolved, which are accompanied with a smell at first but little disagreeable, afterward musty or mouldy, then faint, fetid, slightly ammoniacal, are compounds of carbonated hidrogen gas, carbonic acid gas, and azote gas. These phenomena diminish and grow weaker by degrees, after having continued a longer or shorter time, according to the consistency of the vegetable, which loses much of its substance in matter that evaporates, and leaves only a residuum more or less abundant, of a blackish colour, and containing

taining the moſt fixed of the materials that entered into its compoſition; namely, the earths, the acids that ſaturated them, and part of the carbon which gave it conſiſtency.

4. In theſe conditions, and in theſe phenomena, as well as in the products of the putrid fermentation of vegetables, we manifeſtly perceive the influence of the numerous attractions, which the materials that enter into the compoſition of their texture exerciſe on one another. The hidrogen in particular unites with the oxigen, and flies off as water; or is evolved as gas, carrying with it a portion of the carbon; while a third portion of this principle unites with the azote in plants that contain it, and forms ammonia; and a fourth and laſt part ſtill remains in the reſiduum, which it colours, and to which it ſtill imparts ſmell. The carbon unites in part with the hidrogen evolved; in part with the oxigen, which burns it, and carries it off as an acid; and a part remains in the reſiduum. The oxigen ſeparates itſelf from the plant with each of theſe two principles, with which it unites to make binary combinations.

5. Among the fixed reſults, the reſidues afforded by the putrid decompoſition of vegetables, we muſt particularly diſtinguiſh as uſeful objects, hemp, and other filamentous plants ſteeped, rotten wood, dung, and mould.

SECTION I.

Of the ſteeping of Hemp, Flax, Stipa Tenaciſſima, Spaniſh Broom, &c.

6. THE effect of the ſucceſſive action of water and air on the agglutinated and united fibres of the ſemiligneous ſtalks of filamentous plants, particularly of hemp, flax, the ſtipa tenaciſſima, and Spaniſh broom, when they are kept immerſed alternately in them, are well known: this operation is called rotting, and the places in which it is performed are termed ſteeping pits. Theſe plants are ſteeped for ſome days at the ſides of brooks, rivulets, ſome ponds, and even in the midſt of the water, being kept down with ſtones. The mucous and extractive gluten, which kept the fibres adherent, is diſſolved and decompoſed; the bark is readily detached from the interior woody texture; the cortical layers and their filaments are eaſily ſeparated.

7. Experience proves that running water is far preferable to ſtagnant, though prejudice has impreſſed a contrary opinion on many country people. Boiling in water ſlightly impregnated with alkali may ſupply the place of ſteeping, which, as it is moſt commonly practiſed, is accompanied

companied with an inſupportable ſtench, and a real putrid decompoſition. It is from this laſt well known fact that I conſider hemp, and all other vegetable ſtalks in general that have undergone this proceſs of ſteeping, as a ſort of fibrous ſkeletons, freed by a putrid alteration from every thing that ſurrounded them. This decompoſition is ſtopped in due time, otherwiſe it would attack the fibrous texture itſelf, if it were allowed to continue, and deſtroy the tenacity of the filaments, as happens when the plant is ſteeped too long.

8. With theſe flexible and ſolid fibres are fabricated thoſe delicate and light cloths unknown to the ancients, of which poliſhed nations make the garments they wear next their ſkin. Linen we know has conſiderable ſtrength and durability. Yet by tearing and grinding it, after macerating it in water and ſuffering it to become half rotten, is made that pulp of ingenious invention, which, being diluted and ſuſpended in hot water, ſubſides in a thin layer on very fine ſieves dipped into the fluid, ſo as to form by precipitation thoſe ſheets of paper, which are ſet to dry, and covered with a vegetable or animal glue, that it may be afterward written upon without the ink ſinking into it.

Section II.

Of rotten Wood.

9. DEAD wood, altered upon the ground in different manners, and known by the name of *rotten wood*, is one of the moft fingular refults of the putrid decompofition of vegetables. The foot ftalks of the leaves, the woody peduncles of flowers and fruits, flender twigs, the light ftalks of fhrubby plants or dried herbs, which have acquired a woody nature by deficcation, corrupt, change, and are decompofed; when lying on the ground and heaped together with leaves upon mofs, in hollows where water collects, more or lefs covered or penetrated by this fluid, and at the fame time expofed to the contact of air, we fee them grow brown, blacken, fplit, lofe their cortical layers in little fcales or filaments, and exhibit beneath a yellowifh, brownifh, or white flabby texture, without confiftency, of a mouldy fmell, and in a ftate of decompofition which is called rotten.

10. We fee pieces of folid timber, whole beams or planks, coming to this ftate in the period of a few years, when they are expofed to damp air, or in low places, where the water does not naturally evaporate. Thus the wood of fences, particularly in forefts and courts that

have

have little circulation of air; beams and planks in cellars; floors and partitions in underground apartments, where the air is but little renewed, and remains conſtantly loaded with moiſture; become ſoft, crack, emit a mouldy ſmell, loſe their ſolidity, and at laſt ſeparate into white, pliant leaves and filaments, or into powder in dry weather.

11. Though all the phenomena that ſucceed each other and take place in this ſpontaneous deſtruction of wood have not yet been deſcribed, or perhaps obſerved with ſufficient care, at leaſt ſome have been noticed and mentioned, which it is neceſſary to record here. For inſtance, we know that the wood is phoſphoric, or ſo ſtrongly luminous, during the courſe of this ſlow putrefaction, and almoſt to the end of it, as to exhibit ſingular ſpectacles in the fields and woods. We know, that it conſtantly emits ſuch a ſmell, as is found in the claſs of agarics and ſpunks, the production of which ſeems frequently to be the conſequence of this putrefaction: we know that the mucous, extractive, feculent, oleaginous matters, which form a part of the compoſition of vegetables, are gradually deſtroyed, and eſcape from the ligneous ſubſtance during this decompoſition; and that they are found no more, or at leaſt are found in a ſtate much altered, yet but little aſcertained, and deſerving further examination.

12. When we examine the laſt reſiduum of theſe rotten woods, we remark that they have

loſt,

loſt, beſides their ſolidity and their conſiſtence, the greater part of their primitive matter, weight, and ligneous property. Their combuſtibility is ſingularly diminiſhed: they burn feebly and rapidly; they give out little heat; they leave little cinder, but this cinder is ſtrongly ſaline, and many chemiſts have obſerved, that among the ſalts obtained from it, ſulphate of ſoda is conſtantly found in greater quantity than it is uſual to procure it from vegetable ſubſtances. Theſe firſt facts reſpecting the nature of rotten woods, ſufficiently ſhow, how important it may prove to vegetable phyſics, carefully to obſerve and attend to every thing that concerns the ſpontaneous alterations, to which they are liable.

Section III.

Of Dung.

13. THOUGH at firſt view there appears to be nothing in the ſlow decompoſition of the ſtems of herbaceous plants, and the ſtalks of graſſes, that differs eſſentially from that of other ſolid vegetable matters: yet the ſort of phenomenon they then undergo, and the product they furniſh under the name of *dung*, have a claim on our attention for a few moments, on account of their important uſe in agriculture. By the term dung, however, I do not here underſtand with the generality

generality of farmers that diversified heap, that chaos of animal and vegetable substances, various in their nature, that filth of every kind, that is heaped on the straw which has served as litter to animals, and which, particularly impregnated with their liquid and solid excrements, afterward furnishes land with a very nutritious manure: in this point of view it will be treated of in another place.

14. At present I consider only the pure remains of the culms or herbaceous stalks of all plants, which, after having been heaped together and moistened in such a manner as to be surrounded and even fermented by the air, grow hot, become coloured, separate into pieces, and emit a fetid smell, an aqueous vapour impregnated with carbonated hidrogen gas, and sometimes even ammonia: which grow soft, and partly dissolve into a brown strong-scented fluid, very useful to vegetation, and depositing charcoal by a slow precipitation: and of which another part is reduced into a blackish friable substance, which ultimately becomes pulverulent, and is confounded with the earth, to which it is gradually reduced after passing through the state of mould, which will presently be examined.

15. During this decomposition, which renders these remains of vegetables so fit for meliorating, enriching, manuring, or forming the soils in which they are mixed by the help of the plough; the principles that constitute these vegetable compounds,

compounds, re-acting on one another, are united by the progress of a slow fermentation in an order different from that in which they had been combined by vegetation, partly escape in the form of vapour, and partly dissolve in a thick liquor called *dunghill water*. Some portions of these remains preserve a solid form, notwithstanding they lose the greater part of their texture and organization. All these elements, combined more simply than they were in the compounds of which they made a part, tend gradually to restore to the earth and air what they borrowed from them during their vital movement; and it is by the effect of this decomposition, that dung is of so much use as manure, and for the support of vegetation, as will be said hereafter.

Section IV.

Of Mould.

16. The last stage of the slow and manifestly putrid decomposition of herbaceous stalks, the end of the dung which in this state is said to be exhausted, is its reduction into mould. By this term is implied the pulverulent, blackish, fat residuum, which dung leaves after its total decomposition; called in French *terreau*; because it resembles the state and form of an earth,

and becaufe it adds to the terreftrial globe ftrata, that cover its furface, apparently increafing the extent and depth of it. In fome points of view it may be confidered as the fkeleton of herbaceous ftalks: but we fhould be wrong to fuppofe as formerly, that it confifts folely of the fixed matters, that enter into the compofition of thefe ftalks.

17. In this laft refpect the name of *vegetable earth*, which has been given it, can exprefs only its external appearance or phyfical properties. It muft not be confounded with an earth properly fo called, fince earthy fubftances are frequently the leaft portion of the matters that conftitute mould. The firft analyfis made of it a few years ago by Citizens Giobert and Haffenfratz, fhowed the prefence of oleaginous matters, extractive fubftances, and charcoal ftill containing much hidrogen. Accordingly, when fubjected to diftillation, mould yields odorant elaftic fluids and liquid products. When it is boiled in water, it colours it, and communicates to it tafte and fmell. When it is heated in contact with air, it takes fire, and fometimes inflames with confiderable activity: but indeed it muft be obferved, that if mould be carefully wafhed, organized fragments, ftalks, &c. are almoft always found in it. There have been likewife found in frefh mould, acetites and benzoates of pot-afh, lime, and ammonia, fulphate and muriate of pot-afh, and a kind of faponaceous fubftance already mentioned by Bergman.

18. Among

18. Among the fixed materials we find a remarkable quantity of carbon in a very divided ſtate, carbonate of lime, phoſphate of lime, ſilex, alumine, magneſia, iron, and manganeſe. Sometimes the ſilex in it is very abundant: for it may readily be conceived, that, according to the nature of the plants from which it proceeds, the mould muſt differ in the proportion of its fixed reſiduum, and in its principles. It is aſſerted, that ſmall quartz or rock cryſtals, very regular and very tranſparent, are conſtantly found in it: and there is nothing improbable in this, ſince we know ſo many inſtances of the preſence and ſolution of ſilex in the organs of plants and animals.

19. One of the moſt recent diſcoveries concerning mould and vegetable earth, which at the ſame time moſt forcibly proves the combuſtible and very compound nature of this putrid reſiduum of plants, is that which indicates in this ſubſtance a very ſtrong power of abſorbing atmoſpheric oxigen with much promptneſs, and reducing air to its azote gas. Dr. Ingenhouſz, who made this diſcovery, and Mr. Humboldt, who has confirmed and extended it by ſucceſſive reſearches, have both thought this abſorption ſo ſtriking, that mould might be employed for eudiometrical experiments. We ſhall ſee preſently, that this very remarkable property is of ſuch a nature, as to throw light on vegetation, manures, and ſoils.

20. If we reflect ever ſo little on the concatenation and economy of natural phenomena, we ſhall perceive, that this formation of mould, which is a neceſſary conſequence of the ſucceſſive decay of vegetables, is the grand and ſimple means employed by nature, to furniſh a continual ſupply of food for freſh vegetation; that ſuch is in fact the character of the ſoil of all woody places, that it is one of the ſources of its inexhauſtible fertility, and that thus it makes the ſame primitive matter ſerve continually to develope all the germs that grow, and ſupport their life. It may be ſuppoſed, that art muſt have availed itſelf of this grand obſervation, to imitate the fertility of nature, to increaſe the productions which human induſtry demands, and to prevent lands from being ſpeedily exhauſted, as they would be without this perpetual aſſiſtance.

Article VIII.

Of the ſlow Decompoſition, and various Changes, which Vegetables undergo in the Boſom of the Earth.

1. VEGETABLES and their parts have likewiſe natural modes of deſtruction, different from thoſe which have hitherto been deſcribed, and which are not real fermentations. When they are

are buried under ground, or carried together in a maſs into the ſea; which frequently happens in conſequence of earth-quakes, openings of the ground, the ſinking of cliffs, the fall of rocks or large maſſes of ſnow from the mountains, inundations, torrents, currents, &c.; they are excluded from the contact of air, and moſt frequently from the temperature neceſſary to produce fermentative movements, ſo that they undergo nothing reſembling the vinous, acetous, or even putrid fermentation. Penetrated by aqueous molecules which never quit them, or which, inſinuating themſelves into them from time to time, carry with them ſaline, acid, earthy, metallic, and other particles; or waſhed and agitated continually by maſſes of ſalt water impregnated beſides by a number of matters in a ſtate of ſolution, particularly by various animal productions: they find in the courſe of their very deſtruction the cauſe of new effects and modifications, which change their nature, or which, while they retain a part of their former compoſition, give it a very different turn or faſhion from what it before preſented.

2. When we conſider the ſeveral known changes, different from thoſe produced by fermentation, of which vegetables are ſuſceptible in the very midſt of deſtruction, and by its more or leſs ſlow effect, without our being able to attribute or compare them to their true putrefaction, we find four kinds of products, equally formed by ſubterranean alterations, and equally

deferving to be ftudied in the feries of chemical operations, which nature performs in the large way. In order to appreciate their mutual reports, their differences, their production, and their ufes, I fhall here defcribe them in fucceffion under the heads of

1ft, foffil woods;
2d, turf or peat;
3d, bitumens;
4th, petrified vegetables.

SECTION I.

Of Foffil Wood.

3. IN the interior part of the earth, and particularly along the banks of moft large rivers, we frequently find wood buried ten or fifteen metres deep, ftill very diftinguifhable, not only by the form, texture, and confiftence, but by the great quantity and ftate of the trunks and branches lying together in larger or fmaller heaps. We feldom dig near the banks of running waters, or beneath their beds, without difcovering fuch wood, fometimes in fo great quantity, that we cannot avoid perceiving whole trees, and even parts of forefts, fwallowed up by grand cataftrophes, fuch as we fometimes fee, and which occur ftill more frequently near thofe great rivers of vaft uninhabited continents, the foil

of which is every where covered and loaded with the produce of an ancient vegetation, that has continued through a long ſeries of ages.

4. Theſe foſſil woods are commonly of a brown or almoſt black colour, and of a ſoft and tender conſiſtence, as long as they remain buried. They readily harden, and even become very hard, when they continue ſometime expoſed to the air, ſtill preſerving a dark colour, and acquiring by deſiccation a much finer and cloſer texture than they originally poſſeſſed. Sometimes they are employed with great advantage for certain purpoſes of building, particularly in places neceſſarily more or leſs expoſed to the contact of damp air, as underground apartments, &c. becauſe they are no longer capable of being affected by the humidity of the atmoſphere. Foſſil wood is ſtill extremely combuſtible: it burns with little flame, but gives out great heat: it affords a denſe and heavy charcoal if it be extinguiſhed when half burned. The oil it yields on diſtillation is fetid and nearly ſolid.

5. In all theſe properties we diſcern a ligneous ſubſtance, which has undergone ſome changes: it is not perfectly of the ſame nature as before. The ſtrata of wood penetrated with water have loſt a portion of the mucous, extractive, ſoluble matter, which they contained. They have been reduced more or leſs to the ſtate of a pure woody ſkeleton: even a portion of the external ſubſtance of the ligneous fibres has been decompoſed, and reduced to the form and colour of charcoal;

charcoal: a part of their hidrogen has been taken from them. When the water which impregnates them and keeps them ſeparate is diſſipated, theſe layers contract and preſs cloſely upon each other: hence, reſults that hardneſs, that compact texture, and that ſhining ſurface, which they acquire when cut and poliſhed; and hence, the little flame they emit, when burned in a fire-place. In fine, we perceive that foſſil wood, though ſtill ligneous, is in its progreſs to deſtruction, and that a longer ſtay in the earth would in the end deſtroy it completely, by diminiſhing more and more all the properties of vegetable matter it poſſeſſes. Accordingly, we ſometimes find it friable, no longer capable of becoming dry and ſolid, but crumbling and reducible to a ſort of mould by rubbing.

Section II.

Of Turf or Peat.

6. THE explanation juſt given of the effects produced on wood by moiſt earth, and water filtering through it, which thus reduce it to its coally ſkeleton, is equally applicable to plants buried in the earth. There are likewiſe many low grounds, which, nearly on a level with ſmall rivers, and ſometimes even below it, are alternately covered with earth and left by their

waters, or admit them in ſuch a manner, as to be continually fermented by them. Theſe grounds producing an enormous quantity of plants crowded together, inceſſantly growing, and annually accumulating layer upon layer, their ſoil becomes loaded to a greater or leſs depth with remains of vegetables, or herbaceous ſtalks, interwoven with each other in all directions, of a black and coaly colour, and of a diſagreeable or even fetid ſmell, which indicate a conſiderably advanced ſtage of vegetable decompoſition.

7. Theſe remains, ſtill ſolid and combuſtible, are known by the name of *turf* or *peat*, and the places from which they are taken are called *bogs*, or *turbaries*. Though peat conſiſts of coherent maſſes, belonging to a much larger maſs of one ſingle piece of a ſubterranean depoſit, yet by ſeparating the filaments which compoſe their texture, we may diſtinguiſh ſeveral of the plants, which have contributed to their formation. They are ſeparable into long, ſoft, brown, or black ſtalks, ſometimes indeed of a bluiſh or violet colour, which have loſt the natural conſiſtence of the plants to which they belonged, and are manifeſtly altered in their texture as well as in their nature.

8. When turf is heated in an apparatus for diſtillation, we obtain from it a yellow or reddiſh fetid water, an extremely ſtinking oil, carbonate of ammonia, and carbonated hidrogen gas of a very diſagreeable ſmell. The reſiduum is a coal,

coal, frequently pyrophoric, from which ſome ſalts may be extracted after incineration, particularly muriates and ſulphates of ſoda and potaſh, mixed with phoſphate of lime, calcareous ſulphate, and oxides of iron and manganeſe. Every perſon knows the manner in which turf burns in fire-places and furnaces, the ill ſmell it emits, and the reddiſh ferruginous aſhes it leaves. Attempts have been made with ſome ſucceſs to diveſt it of theſe inconveniencies, by half burning it in cloſe veſſels ſo as to char it like wood. This proceſs has certainly its advantage. It muſt be mentioned however, that this charcoal is inferior to that commonly made from wood; and that it is liable to take fire from the combined action of air and water, ſo that it ought to be kept for uſe in cloſe places well ſecured. I ſaw a yard in Paris filled with this charcoal, induſtriouſly and even ſkilfully manufactured, occupying a vaſt ſpace open to the air. After a few days rain, to which it was conſtantly expoſed, a copious white ſmoke aroſe from it, which was ſoon converted into a flame, and entirely conſumed the charcoal, at the ſame time threatening every inſtant a more general conflagration, by communicating to other combuſtible ſubſtances near.

9. Turf therefore is in reality the reſiduum of plants or herbs half decompoſed, half burned, reduced almoſt to the ſtate of charcoal, analogous in its nature to foſſil wood, which is equally carbonaceous. It is uſed as fuel, where there is

no

no other: it may be very ufeful in forges: its afhes are employed as manure. By lixiviation, falts of ufe in the arts may be obtained from it. There are fome turbaries which are found to contain likewife fulphuret of iron, or pyrites. This compound, fo combuftible in moift air, heats them when they are expofed to it, and even occafions them to take fire. Some of them, fuch as thofe in the environs of Beauvais, are even capable of furnifhing by lixiviation fulphate of iron, which is formed in them by expofure to the air. There is no doubt, that moft turfs may be employed for obtaining from them by diftillation an oil analogous to tar, as Becher propofed in 1683.

SECTION III.

Of Bitumens.

10. Bitumens, are produced like foffil wood and turf from vegetables or parts of vegetables, heaped up and buried in the waters and in the earth, but differ from both of them in being combuftible fubftances without any organic texture or appearance in the greater part of their maffes, which are homogeneous, brittle, and as it were vitreous in their confiftence, when folid; in furnifhing, all without exception, acid or ammonia, when diftilled, and leaving a coal divided

vided in the form of fibres or laminæ. It may easily be known however, that they have belonged to the vegetable kingdom, by their oily nature, by the carbon they contain, and likewise by their vegetable origin being manifest in them, either by the seeds, leaves, or stalks of which they exhibit impressions, or by the ligneous nature which they frequently show at one of their extremities.

11. Formerly they were confounded with sulphur, bearing the same appellations, as they were termed a *mineral sulphur*, while sulphur itself was sometimes called *bitumen*, or *bituminous juice*. They were likewise considered for a time as mineral productions, as terrene oils; and their vegetable origin was not then understood. At present there is no longer any difficulty in distinguishing them from *anthracite*, a species of carbonaceous matter mixed with one-third of its weight of silex and a little iron, which exists in the primitive mountains, and affords no oil; while bitumens, which are found only in strata of the second or third order, contain, or yield when acted on by fire, more or less oil. It is evident that bituminous productions cannot be considered as belonging to the class of minerals; or at least of being in some respects related to it, merely because they are found in the earth among fossils.

12. Four species of bituminous matters should be distinguished: *bitumen*, properly so called, *coal*, *jet*, and *amber*. Their specific differences

ences are very well marked by the following characters:

Bitumen is fluid or soft: it yields no ammonia on distillation; it leaves very little coally residuum.

Coal affords much ammonia, and leaves much coally residuum after distillation, much earthy matter after incineration.

Jet is susceptible of a fine polish: when distilled, it gives out a liquid acid.

Amber is transparent: it furnishes a concrete acid by sublimation.

We must examine the properties, origin, nature, and use of each species in particular.

A. *Bitumen.*

13. At present, the name of *bitumen* is confined to oleaginous fossil substances, which give out no ammonia when acted on by fire, which emit no fetid smell when burned, and which after they are burned leave little earthy residuum.

14. There are two principal varities of bitumen, one more or less fluid from the lightness of naphtha to the consistency of pitch. This variety is called *naphtha, petroleum,* or *pissasphaltum,* according to its liquidity. The second, which is solid, or nearly so, is called *asphaltum.*

FIRST VARIETY.

Liquid Bitumen; Petroleum.

15. THE name of *petroleum*, or *rock-oil*, has been given to a fluid bituminous ſubſtance, which flows between ſtones, on rocks, or in different parts of the ſurface of the earth. This oil differs in lightneſs, ſmell, conſiſtence, and inflammability. Authors have diſtinguiſhed a pretty conſiderable number of ſub-varieties of it. They have given the name of *naphtha* to the lighteſt, moſt tranſparent, and moſt inflammable petroleum; that of *petroleum*, properly ſo called, to a liquid bitumen of a deep brown colour; and laſtly, that of *mineral pitch* to a black, thick bitumen of little fluidity, tenacious, and ſticking to the fingers. The following are the ſub-varieties deſcribed by Wallerius and ſeveral other naturaliſts.

VARIETIES.

1. WHITE naphtha.
2. Red naphtha.
3. Green or dark naphtha.
4. Petroleum mixed with earth.
5. Petroleum exuding from ſtones.
6. Petroleum floating on water.
7. Mineral pitch, or maltha.

8. Piſſaſ-

8. Piſſaſphaltum. This is of a mean conſiſtence between that of common petroleum, and that of aſphaltum, or Jew's pitch.

16. The different naphthas are found in Italy, in the neighbourhood of Modena, and at Monte Ciaro, twelve leagues from Placenza. Kempfer ſays, in his *Amœnitates exoticæ*, that a great quantity is collected in ſeveral parts of Perſia; and that a place in India, where it burns, is ſaid to contain the devil, whom God has ſhut up there. Petroleum flows in Sicily, and in ſeveral parts of Italy; in France at the village of Gabian, in Languedoc, and in Alſace; at Neufchâtel, in Switzerland; in Scotland; and in other places. Piſſaſphaltum and mineral pitch were formerly obtained from Babylon, in conſtructing the walls of which place they were employed; from Raguſa, in Greece; and from the marſh of Samoſata, the capital of Commagene, in Syria. At preſent they are procured from the principality of Neufchâtel, and from Vallengin, Puits, Pege, a league from Clermont-Ferrand, in the department of Puy de Dome, and ſeveral other places.

17. With regard to the different ſub-varieties mentioned, it is to be obſerved, that they all appear to have the ſame origin, and that they differ from one another only by ſome particular modification. Moſt naturaliſts and chemiſts attribute the formation of petroleums to the decompoſition of ſolid bitumens, by the action

of

of the ſubterraneous fires. They obſerve, that naphtha appears to be the lighteſt oil, which the fire firſt diſengages; that what ſucceeds it, aſſuming colour and conſiſtency, forms the different ſorts of petroleums; and that the latter, by uniting with ſome earthy ſubſtances, or being altered by acids, acquire the characters of mineral pitch, or piſſaſphaltum. In ſupport of this opinion, they make a very exact compariſon of the phenomena exhibited by the diſtillation of amber, which in fact affords a ſort of naphtha, and a petroleum more or leſs brown, according to the degree of heat and time of the operation. Finally, they obſerve, that nature frequently preſents us with all the ſpecies of petroleum, from the lighteſt naphtha down to mineral pitch, in the ſame ſpot, as in the caſe of the fluid bitumens obtained from Monte Feſtino near Modena.

18. For the reſt, the chemical properties of petroleum have not yet been examined with ſufficient care. We only know, that naphtha is very volatile, and ſo combuſtible, that it catches fire if any thing burning be brought near it: it ſeems even to attract flame in conſequence of its volatility. From the brown petroleum we obtain an acid phlegm, and an oil, which at firſt reſembles naphtha, and which becomes coloured as the diſtillation advances. What remains in the retort is a thick matter like piſſaſphaltum, which may be rendered dry and brittle as aſphaltum, and reduced entirely to the

the coally ſtate by a ſtronger fire. Alkalis have little action on petroleum: ſulphuric acid darkens its colour, and renders it thicker; nitric acid inflames it, as it does volatile oils: it eaſily diſſolves ſulphur; it is coloured by metallic oxides: it unites with amber, part of which it ſoftens and diſſolves by means of heat.

19. The different kinds of petroleums are employed for different purpoſes in the countries where they abound. Kempfer informs us, that in Perſia they are uſed to give light, and are burned in lamps by means of wicks. They may likewiſe be uſed to give heat. Lehman ſays, that for this purpoſe ſome naphtha is poured on a few handfuls of earth, and kindled with paper; when it immediately burns briſkly, but diffuſes a thick and very copious ſmoke, which adheres to every thing, and the ſmell of which is very diſagreeable. It is ſuppoſed too, that petroleum enters into the compoſition of the Greek fire. The thick petroleum is employed likewiſe for making a very ſolid and very durable mortar. By boiling piſſaſphaltum with water an oil is obtained from it, which is uſed for tarring ſhips. In India the flame produced by a burning petroleum is worſhipped, and the heat it emits is uſed for dreſſing victuals, and burning lime.

20. Laſtly, ſome phyſicians have ſucceſsfully employed petroleum in diſeaſes of the muſcles; in palſy, debility, &c. by rubbing or fumigating the ſkin with it. Van Helmont conſidered fric-

tions with petroleum as a very good remedy for frozen limbs, and recommended them as an excellent preservative against the action of cold.

Variety II.

Solid Bitumen, or Asphaltum.

21. Asphaltum, or Jews pitch, called likewise *funeral gum, amber of Sodom, mountain pitch, balsam* of *mummies*, &c. is a black, heavy, solid, and somewhat shining bitumen. It breaks easily, and its fracture is vitreous. A thin slip of this bitumen appears red when held between the eye and the light. Asphaltum has no smell when cold, but acquires a slight smell by rubbing. It is found on the waters of the lake Asphaltites, or Dead Sea, in Judea, near which were anciently the cities of Sodom and Gomorrah. The people, incommoded by the smell which this bitumen diffuses as it lies on the water, and encouraged by the profit they gain by it, collect it carefully. Lemery says, in his Dictionary of Drugs, that the asphaltum exudes as a liquid pitch through the ground which is covered by the Dead Sea, and that rising to the surface of the water, it is there condensed by the heat of the sun, and by the action of the salt, which that water contains in abundance. It is met with likewise on many lakes in China. Wherever pissasphaltum is found, the portion that is dried in the air becomes a species of asphaltum,

phaltum, which may be used for the same purposes as that of the lake of Judea. What is found near Neufchâtel, in Switzerland, is thus employed.

22. Naturalists are divided in opinion respecting the origin of asphaltum, as of all the bitumens. Some imagine it to be a mineral production, formed by an acid united with an unctuous matter in the bowels of the earth: others consider it as a resinous vegetable substance, buried in the earth, and altered by mineral acids. The most general and most probable opinion is, that its origin is the same with that of amber; and that it is formed by this last bitumen, which has undergone the action of a subterraneous fire. This opinion is founded on the circumstance that amber, melted and deprived of a part of its oil and salt by the action of fire, becomes black, dry, brittle, and perfectly similar to asphaltum: but it can be confirmed only by a comparative analysis of asphaltum; and this residuum of amber and asphaltum has not yet been examined with the accuracy necessary to ascertain this analogy.

23. Asphaltum, when exposed to the fire, melts, swells up, and burns, emitting flame, and a thick smoke, the smell of which is strong, acrid, and disagreeable. By distillation we obtain from it an oil coloured like brown petroleum, and an acid water. By fusion it mixes intimately with sulphur, phosphorus, several metallic oxides, and particularly fixed and vola-

tile oils, resins, and gum-resins. It is no way altered by alcohol, which does not touch the bitumens in general. The action of ether on these substances is a little more perceptible, though very slight.

24. The Arabs and Indians use asphaltum instead of tar to coat ships. It is used in the composition of the black varnishes of China, and in fire-works to burn on water. The Egyptians employed it for embalming dead bodies; but only for those of the poor, who could not pay for more costly antiseptics. Wallerius asserts, that some merchants prepared a sort of asphaltum with inspissated pitch, or by melting pitch, and mixing it with a certain quantity of real asphaltum: but this fraud may be detected by means of alcohol, which dissolves the pitch intirely, but only acquires from the asphaltum a pale yellow colour.

B. *Coal.*

25. Coal has received the names of *pit-coal, stone-coal, lithanthrax*, from its combustible property, and the use made of it in several countries. It is found in the earth, most commonly below stones of less or greater hardness, sand-stones, and aluminous and pyritous schistus. These last constantly exhibit the impressions of several vegetables of the family of ferns, most of which, according to the observation of Bernard de Jussieu, are exotic. The bamboo and barana

banana have been diſtinguiſhed in the pit-coal of Alais. It lies more or leſs deep in the earth. It is always arranged in ſtrata, either horizontal or inclined, but more frequently the latter. The beds or ſtrata of which it conſiſts differ in thickneſs, conſiſtency, colour, ſpecific gravity, &c. Frequently over this bitumen are found beds of ſhells, impreſſions of fiſh, and foſſil madrepores, of greater or leſs extent, which has led ſome moderns to ſuppoſe, particularly Citizen Parmentier, that pit-coal has been formed in the ſea by the depoſition and alteration of the oily or fatty matter of marine animals. Moſt naturaliſts conſider it as the product of a reſiduum of wood buried and altered by the water and ſalts of the ſea. We frequently find above coal, plants and wood partly diſtinguiſhable, and partly converted into coally bitumen. Its formation appears to be owing to the decompoſition of an immenſe quantity of land and ſea-plants, and to the ſeparation of their oil, united with alumine and calcareous matter. We cannot deny that animal matters likewiſe enter into its compoſition.

26. Beds of coal are worked as mines, by ſinking pits and hollowing out rooms, the bitumen being got out with pick-axes, or a ſort of mattocks. The workmen who are employed in this are often expoſed to the danger of loſing their lives by the elaſtic fluids diſengaged from it. This kind of mephite is called *choke-damp*, *black-damp*, or *ſtyth*, by the colliers; it extinguiſhes

extinguishes the lamps, and appears to be carbonic acid gas. In these mines too a very deleterious kind of carbonated hidrogen gas is evolved, which sometimes produces dangerous explosions.

27. Coal is very abundant in nature. It is found in England, Scotland, Ireland, Hainault, Liege, Sweden, Bohemia, Saxony, &c. Several departments of France furnish a great deal, particularly those which occupy what was formerly Burgundy, the Lyonnese, Forez, Auvergne, Normandy, &c. Though the English greatly excel the French in the art of working coal, and employing it for the use of man; and though they have expended large sums, and executed magnificent works for the purpose, such as the subterranean canal of the Duke of Bridgewater, which is near five thousand metres long; yet France possesses more wealth of this kind than England; and its industry, roused by necessity, will soon equal that of its neighbour and rival.

28. Coal has been distinguished into *stone-coal* and *earth-coal*, according to its hardness or friability: but the manner in which it burns, and the phenomena it exhibits in combustion, afford much more important characters to discriminate its different varieties. In this point of view Wallerius distinguishes three: 1st, the *scaly-coal*, which remains black after being burned; 2d, the compact and foliaceous *coal*, which, after having been burned, afford a spongy

ſpongy ſubſtance reſembling ſcoriæ: 3d, the *fibrous-coal*, like wood, which is reduced to aſhes by combuſtion.

29. Coal heated in contact with air, and ſome other ſubſtance in a ſtate of combuſtion, kindles with a ſlowneſs and difficulty proportionate to its gravity and compactneſs. Once kindled, it emits a ſtrong and laſting heat, and remains burning a long time before it is conſumed: it may even be extinguiſhed and employed ſeveral times over again. Its inflammable matter appears very denſe, and as it were fixed by ſome other incombuſtible ſubſtance, which retards its deſtruction. In burning it emits a ſtrong and peculiar ſmell, which however is by no means ſulphureous, when the coal is very pure, and contains no pyrites. The combuſtion of this bitumen appears very analogous to that of organic ſubſtances, as it is capable of being ſtopped, and divided into two periods. In fact, the oily combuſtible part, the moſt volatile the coal contains, is diſſipated in flame by the firſt action of the fire: and if a ſtop be put to the combuſtion, when all this principle is diſſipated, the bitumen retains only the moſt fixed and leaſt inflammable portion of its oil, reduced to a truly charred ſtate, and combined with an earthy baſe. By a proceſs of this kind, the Engliſh prepare their coke, which is nothing but coal deprived of its oily and fuſible part by the action of fire.

30. We

30. We may ſee clearly what paſſes in the action of fire upon coal, by heating this bitumen in cloſe veſſels, and in an apparatus for diſtillation. Thus we obtain from it an ammoniacal water, concrete carbonate of ammonia, and an oil, which grows darker coloured and heavier in proportion as the diſtillation advances. At the ſame time a great quantity of inflammable elaſtic fluid paſſes over, which is conſidered as an oil in a ſtate of vapour, but which is hidrogen gas mixed with azote gas, carbon in ſolution, and carbonic acid gas. What remains in the retort is a ſcorified coally ſubſtance ſtill capable of burning: it is the Engliſh coke. If we carefully obſerve the action of the fire on very pure coal, we ſhall perceive it evidently ſoftened, and ſeemingly undergoing a ſemi-fuſion: now as we may imagine this ſtate to be detrimental in the fuſion of ores, it is of eſſential importance to deprive the bitumen of this property. In this we may ſucceed by diveſting it of the principle, which occaſions it thus to ſoften, namely, of the oil which it contains in great abundance, and by reducing it to a ſtate ſimilar to that of charcoal made from vegetable ſubſtances. It is to be obſerved, that the pretty conſiderable quantity of ammonia furniſhed by coal favours the opinion of its animal origin: ſince, as will be ſeen in another place, the ſubſtances belonging to this claſs of compounds always yield ammonia when diſtilled. This analyſis

lyſis is effected in the great in particular works erected in Scotland by Lord Dundonald. The oil, which is collected in reſervoirs cooled by the water of a river that paſſes underneath, is uſed as tar; the ammonia is employed for making ammoniacal muriate; and the reſiduum is very good coke. Citizen Faujas has imported this uſeful art into France; and the experiments, which he has made on a ſmall ſcale at the Muſeum of Natural Hiſtory, have ſucceeded extremely well: notwithſtanding this, however, no works have yet been erected for carrying on this manufacture. After the combuſtion of coal, its aſhes contain ſulphates of iron, magneſia, lime, alumine, or, if the combuſtion have been very rapid, the baſes of theſe ſalts.

31. Coal is a combuſtible every where uſeful, but particularly in countries where there is no wood. It is uſed for all domeſtic purpoſes; and there is no reaſon to fear the dangers which ſome have aſcribed to its uſe. The ſulphureous vapour, which it is ſuppoſed to emit during combuſtion, need not be dreaded, ſince the moſt accurate analyſis has proved to all chemiſts, that coal, when pure, contains not a particle of ſulphur. Hence, we ſee how falſe and deceitful are the pretenſions of thoſe ignorant men, who announce proceſſes for deſulphurating this bitumen. Another conſideration, which ought to induce us to derive all the advantage we can from coal, particularly in France, is, that as the working of mines conſumes enormous quantities

of

of charcoal, there is reafon to apprehend we fhall, fome time or other, be in want of wood. It is particularly in works of this kind that we ought to endeavour to employ coal, as the Englifh have long done: indeed its ufe begins to be eftablifhed in feveral fuch works, of which the famous iron founderies at Creufot, near Mount Cenis, and at Autum, afford great and ufeful examples.

32. Purified coal, falfely called *defulphurated*, is nothing but that which is deprived of its oil by the action of fire. This fort of charcoal burns without fmoke, without growing foft, without any ftrong fmell; in a word, it is real coke; and on account of thefe properties, is preferred for burning in the fire-places of rooms.

One of the great inconveniences of coal, befide the very abundant and thick fmoke it emits, which blackens all the furniture in a room, is, that the very rapid and copious current of air it requires for its combuftion, carries up and volatilizes part of its afhes, which adhere to every thing around: but both thefe inconveniences may be remedied in great meafure by conftructing the fire-place in a proper manner; fo that the whole of the current excited by the combuftion may pafs up the chimney, without any part of it being returned into the room.

The great utility of this combuftible in France will be found more particularly in manufactories of every kind; and its ufe will occafion

a very

a very great saving of wood for the purposes of building and common fires.

C. *Jet.*

33. Jet, the *gagates* of the Latins, the black amber of Pliny, the *pangitis* of Strabo, is black, hard, compact, vitreous in its fracture, and capable of acquiring a fine polish by friction, which renders it electric. It is destitute of smell, but becomes slightly fetid when heated. It softens and swells up without melting completely: it burns and diffuses a strong smell during combustion.

34. We cannot mistake its origin, when we examine it attentively in the places where nature offers it to our view. Naturalists were mistaken in supposing that it was asphaltum indurated by time. It is manifestly the product of a slow decomposition of wood buried in the earth. In collections and cabinets we find pieces of wood converted into jet in one part, and yet evidently ligneous throughout the greater portion of their substance. At St. Jean-de-Cucule, near Montpellier, and at Nismes, several trunks of trees, very distinguishable by their shape, have been found changed into jet. Citizen Chaptal mentions a shovel converted into jet throughout. The jet of Vachery, in the [illegible]-devant Gevaudan, perceptibly exhibits the [illegible]ture of walnut wood; and that of beech is [illegible] in the jet of Bosrup, in Silesia.

35. By

35. By diſtillation, we extract from it a little water and a brown oil, which is rectified by cohobation with argil. It yields leſs than fat coal. The ſmell it emits in burning, and which diſtinguiſh its products, without being fetid like that of coal, is more potent, more pungent, and more ſenſibly bituminous, or more analogous to that of amber, which will be mentioned preſently.

36. Jet is wrought for making trinkets and ornaments for mourning. Bracelets, buttons, necklaces, and ſnuff-boxes, are made of it at Wirtemberg and in France at Sainte-Colombe near Caſtelnaudary. A quarry of it too is wrought at Beleſtat, in the Pyrenees.

D. *Amber.*

37. Amber, or *yellow-amber*, as it is ſometimes called, is the moſt beautiful of all the bitumens in external appearance. It is in irregular pieces, of a yellow colour, ſometimes reddiſh or brown, tranſparent or opaque, formed of coats or layers, and is ſuſceptible of a very fine poliſh. When it is rubbed ſome time, it becomes electric, and capable of attracting ſtraws. By the ancients, who were acquainted with this property, it was called *electrum*, whence is derived our word *electricity*.

38. This bitumen is of a pretty hard conſiſtence, approaching to that of certain ſtones; which has induced ſome authors, particularly Hartmann,

Hartmann, a naturalift who lived near the conclufion of the feventeenth century, to rank it among the gems. It is friable, however, and brittle. The ancients too reckoned it in the number of precious minerals; and confidered it as approaching the diamond: accordingly, their poets have given it a place in fable. Some of thefe feigned it to be the tears of the fifters of Meleager, changed into birds, and weeping for their brother: others the tears of the fifters of Phaeton, which were converted into amber as they fell into the waters of the Po.

39. When amber is powdered it emits a fomewhat pleafing fmell. Within it are frequently found infects very well preferved, and very diftinguifhable; which proves that it has been fluid, and in this ftate enveloped the fubftances we find in it. Amber is moft frequently buried at a greater or lefs depth. It is found under coloured fands, in little incoherent maffes difperfed on beds of pyritous earth; and over it is obferved wood impregnated with a blackifh bituminous matter: whence it is fuppofed to be formed by a refinous fubftance, which has been altered by the fulphuric acid of the pyrites. It floats too on the borders of the fea, and is collected on the fhores of the Baltic in ducal Pruffia. The mountains of Provence, near the city of Sifteron, the Marquifate of Ancona, and the Duchy of Spoleto in Italy, Sicily, Poland, Sweden, and feveral other countries, likewife furnifh it.

40. The

40. The colour, texture, tranſparency, and opacity of this bitumen have occaſioned a conſiderable number of varieties to be diſtinguiſhed, which may be reduced to the following according to Wallerius:

1. White tranſparent amber;
2. Tranſparent amber of a pale yellow;
3. Tranſparent amber of a lemon colour;
4. Tranſparent amber of a golden yellow; the *chryſeleƈtrum* of the ancients;
5. Tranſparent amber of a deep red;
6. White opaque amber;
7. Yellow opaque amber;
8. Brown opaque amber;
9. Amber, coloured green, or blue, by extraneous matters;
10. Veined amber.

It is not improbable that amber exiſts in a cryſtalline form, and perhaps it will be found like ſulphur cryſtallized in oƈtahedrons.

41. A ſtill greater number of varieties might be diſtinguiſhed by the accidental circumſtances which it exhibits interiouſly: but the reader ought to be informed, with reſpeƈt to the price attached to ſpecimens of amber, remarkable for their ſize, tranſparency, and the inſeƈts in a ſtate of good preſervation that they contain within them, that it is poſſible to be deceived in this article, as ſeveral perſons poſſeſs the art of giving it tranſparency, of colouring it as they think proper, and of ſoftening it ſufficiently to be able to introduce into it foreign matters. Wallerius informs

informs us, that the gold coloured amber always owes its tranſparency to nature; and that what has been rendered tranſparent by art is always of a pale hue.

42. Though it is very probable, that this bitumen owes its origin to reſinous vegetable matters, ſeveral naturaliſts have entertained different opinions reſpecting its formation. Some have conſidered it as the hardened urine of certain mammiferous animals: others as an earthy juice, which the ſea has ſeparated, and which, being thrown on the ſhore by its waves, has there been dried and hardened by the rays of the ſun. The latter have diſtinguiſhed it as a peculiar mineral fluid. Such was the opinion of Philemon, an ancient naturaliſt quoted by Pliny; and it was afterward revived by George Agricola. Frederick Hoffmann imagined, that amber was formed of a light oil, ſeparated from bituminous wood by heat, and inſpiſſated by the acid of vitriols. This opinion of Hoffmann we cannot admit: for how is it to be conceived, that an oil, ſeparated in the bowels of the earth, ſhould contain animals, which live only on its ſurface? Hitherto it has been believed, that amber was produced by a reſinous juice, which at firſt flowed liquid from ſome tree: that this juice, buried at a greater or leſs depth in the earth by the changes that have taken place on its ſurface, has been impregnated and hardened by mineral and ſaline vapours circulating in the interior parts of the globe. There is no probability of its

its having been altered by concentrated acids, for experience teaches us, that the action of these acids would have blackened it, and reduced it to the ſtate of charcoal. Pliny thought that amber was nothing but the reſin of the fir, hardened by the autumnal cold. Mr. Girtanner believes it to be a vegetable oil, rendered concrete by the acid of ants. According to this author it is the ſpecies that Linnæus calls *formica rufa*, by which it is prepared. Theſe inſects inhabit the ancient foreſts of firs, where the foſſil amber is found, which is ductile as melted wax, and becomes hard in the air.

43. Amber does not melt on expoſure to the fire without a pretty ſtrong heat: it ſoftens and ſwells a great deal, without flowing in drops, which diſtinguiſhes it from the reſins, as thoſe melt completely. When it is heated in contact with air, it inflames, and diffuſes a very thick and highly ſcented ſmoke. Its flame is yellowiſh, variegated with green and blue. After combuſtion it leaves a *ſhining black* coal, which yields by incineration a very ſmall quantity of a brown earth. Bourdelin ſays, in his paper on amber (Acad. 1742) that he obtained not quite a gramme of this earth by burning a kilogramme of amber in a teſt. Two hectogrammes and half of the ſame bitumen, burned and calcined in a crucible, afforded him in a ſecond experiment two thirds of a gramme of earthy reſiduum, from which he obtained iron by the help of the magnet.

44. If

44. If amber be diſtilled in a retort, and by a graduated fire, we firſt obtain phlegm of a red colour, which is manifeſtly acid: this acid liquor retains the ſtrong ſmell of the amber. Afterward a volatile acid ſalt comes over, which cryſtallizes in ſmall white or yellowiſh needles in the neck of the retort: to this ſalt ſucceeds a light, colourleſs oil, of a very briſk ſmell. This oil gradually grows coloured as the fire gets ſtronger, and becomes at length brown, blackiſh, thick, viſcous, like the empyreumatic oils. While theſe two oils are coming over, a certain quantity of volatile acid ſublimes, which is more and more coloured. After this operation there remains in the retort a black maſs, having the ſhape of the bottom of the veſſel, brittle, and reſembling aſphaltum. George Agricola made this obſervation on the reſiduum of amber after diſtillation near three centuries ago. If this operation be conducted with a gentle and well managed fire, and if a large quantity of amber be employed, all theſe products may be obtained ſeparately by changing the receiver. In general they are received into one veſſel, and rectified afterward by a gentle heat. By this rectification the acid loſes part of its colour. The oil, which becomes black toward the end of the operation only becauſe it carries with it a portion of coally matter, and becauſe the acid has re-acted on its principles, may be rendered very clear and very light by ſeveral ſucceſſive diſtillations. Rouelle the elder has given a very good proceſs for ob-

taining it in this ſtate by a ſingle operation. For this purpoſe the oil muſt be put *with ſome water into a glaſs alembic,* and diſtilled with a heat equal to that of boiling water. The pureſt portion, which alone is volatile at this temperature on account of its lightneſs, comes over with the water, on the top of which it collects. If it be intended to continue in this ſtate, it muſt be kept in ſtone bottles; for the rays of light, that permeate glaſs, will turn it yellow, and even brown, after a time.

This analyſis demonſtrates, that amber is formed of a large quantity of oil combined with an acid. It contains alſo a very ſmall quantity of earth, the nature of which has not been examined, and a few particles of iron.

Oil of amber appears to approach the volatile oils: it has their volatility, their ſmell; it is very inflammable; it appears capable of forming ſoaps with alkalis.

45. The ſuccinic acid, which was at firſt called *volatile ſalt* of amber, was conſidered for ſome time as an alkaline ſalt. Glaſer, Lefevre, Charas, and John Maurice Hoffmann, profeſſor at Altdorf, were of this opinion. Barchuſen and Boulduc ſenior were the two firſt chemiſts, who diſcovered the acid nature of this ſalt toward the end of the ſeventeenth century. All the chemiſts ſince them have adopted this diſcovery, but they have not agreed concerning the nature of this acid. Frederick Hoffmann, conſidering that amber was found in Pruſſia, under ſtrata of

ſubſtances

substances abounding with pyrites, supposed this salt to be formed by sulphuric acid. Neuman appears to have entertained the same opinion. Bourdelin, in the paper quoted above, relates several experiments he made to ascertain the nature of this acid. He observes in the first place, that the acid of amber, obtained by the distillation of this bitumen, however white and pure it may be, always contains some oleaginous matter: to this matter no doubt it owes its smell with the sort of combustibility it possesses, which it exhibits when thrown on burning coals. He tried several means of freeing it from this substance: alcohol would not answer his purpose: fixed alkali alone, digested on amber with a view to take from it its fat and oily part, and obtain its salt separate, was equally unsuccessful; for it only dissolved a little bitumen, and acquired a lixivial and salt taste like muriate of soda. In fine, Bourdelin could discover no better process for uniting the acid of amber pure and deprived of oily matter with fixed alkali, than detonating a mixture of two parts of nitre with one part of this bitumen. He lixiviated the residuum of this detonation with distilled water. This lixivium was of an amber colour: it precipitated the nitric solution of silver in white flakes, and that of mercury of the same colour. Several other metallic solutions were equally decomposed by it: but Bourdelin considered only these two as conclusive. They appeared to him to show, that the acid of amber is the same with that of marine

salt,

falt, fince it exhibits the fame phenomena with the nitric folutions of mercury and filver. The lixivium of the detonation of amber with nitre, having been fuffered to evaporate in the open air, afforded a mucilaginous fubftance, in the midft of which were gradually depofited elongated fquare cryftals, the figure of which, their falt tafte, their decrepitation on burning coals, and particularly their confiderable effervefcence, as well as the fmell of muriatic acid which they emitted, when concentrated fulphuric acid was poured upon them, indicated to our author, that this muriatic acid was united with the bafe of nitre in them.

46. Notwithftanding this analyfis, which is very accurate for the time when Bourdelin made it, the chemifts who have fince examined the acid of amber have not found it analogous to the muriatic acid, but have difcovered all the characters of an oily vegetable acid in it. Bergman, who appears to have adopted this opinion, gives the following details of the properties and elective attractions of this fubftance.

The fuccinic acid, obtained by fublimation, and purified by fucceffive folutions and cryftallizations, forms cryftallizable and deliquefcent neutral falts with pot-afh and ammonia.

With foda it yields a falt, which does not attract the moifture of the air.

United with lime, and with barites, it produces falts but little foluble. Magnefia forms with it a thick fubftance like gum.

It

It diſſolves metallic oxides, and the ſuccinates produced by theſe ſolutions are moſt of them cryſtallizable and permanent.

Barites, lime, and magneſia, according to him, take the ſuccinic acid from pot-aſh and ſoda. Barites decompoſes the ſuccinates of lime and magneſia, and lime-water precipitates magneſia from its union with this acid.

47. The examination of the chemical properties of this bitumen has been carried no farther. Even the manner in which acids are capable of acting on it is not known. Frederic Hoffmann aſſerts, that it may be entirely diſſolved in lixivium of cauſtic alkali, and in ſulphuric acid. We know too, that the volatile oil of amber is capable of uniting with cauſtic ammonia, and forming by ſimple mixture and agitation a ſort of liquid ſoap, of a milky white colour, and a very pungent ſmell, which is prepared in the ſhops under the name of *eau-de-luce*: and laſtly, that this ſame oil diſſolves ſulphur by the help of a ſand-heat, and forms a preparation called ſuccinated balſam of ſulphur.

48. Amber is employed in medicine as an antiſpaſmodic: it has been recommended in hyſterical affections, ſuppreſſed menſtruation, gonorhoea, fluor albus, &c. It is adminiſtered in its native ſtate, after having been waſhed with warm water, and reduced to a fine powder by levigation. It is particularly uſed for corroborant and reſolutive fumigations, the powder of this bitumen being thrown on a hot brick, and the

the fumes it emits being directed to the part on which it is intended to act.

The liquid acid of amber, and its concrete acid, are both considered as pectoral, incisive, cordial, and antiseptic. They are likewise prescribed as powerful diuretics.

The oil of amber is employed externally and internally for the same purposes as amber itself; but it is administered in smaller doses, as its activity is greater.

The succinated balsam of sulphur, which is given in doses of a few drops in appropriate liquors, or mixed with other substances to form pills, has been found beneficial in humoral and pituitous affections of the lungs, kidneys, &c.

A syrup is prepared with the liquid acid of amber and opium, called syrup of amber, which is administered with advantage as anodyne, antispasmodic, and a soother of pain.

The *eau-de-luce*, which is prepared by dropping a few drops of oil of amber into a phial full of caustic ammonia, and shaking the mixture till it has acquired a milky white colour, has long been used as a verv active stimulant in syncope: it is held to the nostrils, the nerves of which it stimulates; and by the shocks it excites, it reanimates the motions of the fluids, and revives the patient.

49. The finest pieces of amber are cut and turned in the lathe to make vases, heads for canes, necklaces, bracelets, snuff-boxes, &c. Trinkets of this kind are no longer prized among

among us, ſince diamonds and precious ſtones have been in faſhion; but they are ſent to Perſia, China, and ſeveral other countries, where they are ſtill eſteemed as great rarities. Wallerius ſays, that the moſt tranſparent pieces may be uſed for making microſcopes, burning mirrors, priſms, &c. It is ſaid, that the King of Pruſſia has a burning mirror of amber a foot in diameter; and that there are in the cabinet of the Duke of Tuſcany a pillar of amber ten feet high, and a very fine chandelier made of the ſame ſubſtance. Two pieces of this bitumen may be united into one by wetting them with a ſolution of pot-aſh, and joining them together after heating them.

Section IV.

Of Petrified Wood.

50. The laſt alteration to be conſidered in vegetables buried in the earth relates to what is called petrified wood, or petrified vegetable ſubſtances in general. A word or two will be ſufficient, to give a proper idea of this pretended alteration. It is a great error to ſuppoſe, that a vegetable ſubſtance is converted into ſilex, as the term of petrified wood ſeems to imply. We cannot doubt, however, that there exiſt foſſil ſilicified ſubſtances, which exhibit the form and

 texture,

texture, not merely of wood in general, but even of particular kinds of wood. In reality it is not from the appearance of ſimple fibres, as is ſo often done, that we can diſtinguiſh a petrified wood. Moſt of the ſpecimens we find under this name in collections of natural hiſtory are by no means real ligneous ſubſtances, they are only ſpecies of jaſper with lines or ſtreaks in the ſhape of fibres. For a foſſil to be juſtly ranked in the genus of petrified wood, the ligneous fibres, or rather what occupies their place, muſt be arranged in concentric and annual layers, and beſides, the prolongations of the medullary ſubſtance, iſſuing from the centre and ſpreading to the circumference, muſt be diſcernible among them.

51. Where this laſt mentioned ſtructure exiſts, it announces a petrified wood, and it is the only ſtructure that does ſo inconteſtibly. At the ſame time it is well known, that we are not by this to underſtand the original woody ſubſtance entire, with its figure, texture, and dimenſions, to be converted into ſiliceous matter: it is neceſſary to form a different idea of this foſſil, bearing as it does an organic appearance. The wood, the tree, the leaves, the fruit, or whatever other vegetable ſubſtance is improperly termed petrified, has been deſtroyed gradually, and almoſt atom by atom, in a moiſt earth, where it has left a hollow mould, as gradually filled up by ſiliceous earth, which the water has brought thither. Thus it is not in reality wood petrified,

but

but fimply wood replaced by filiceous matter, mixed likewife with other earths and with metallic oxides. This kind of filicification therefore, is a proof of the complete deftruction of the vegetable matter, and of the difappearance of every thing that conftituted its elements. There is nothing beyond this in the alterations, of which vegetables are fufceptible.

SIXTH

SIXTH ORDER OF FACTS

RESPECTING VEGETABLE COMPOUNDS.

Of the Chemical Phenomena, which living Vegetables exhibit, or Vegetable Phyſiology explained by Chemical Powers.

Article I.

Of Vegetables conſidered as a ſort of Chemical Implements or Apparatuſſes.

1. IN the beginning of this ſection I remarked, that vegetables might be conſidered as beings intended by nature to begin the organization of crude matter, to form triple combinations of ſimple ſubſtances, compounds to which nothing analogous can be found among foſſils properly ſo called, to diſpoſe theſe primitive materials of the earth and atmoſphere in order to become the ſource of life, and conſequently to eſtabliſh a communication, or uninterrupted paſſage, between minerals and animals; ſo that the life of animate beings could not be maintained without the proceſs of vegetation.

2. From this phenomenon, now ſufficiently proved, it follows, that plants are truly chemical apparatuſſes or implements, employed by nature to produce combinations, which would not take

place without thefe implements, and which cannot exift without vegetable organization: but nature, as admirable in the fimplicity of her means, as in the conftancy and regularity of her operations, finds in one and the fame mechanifm both vegetable organization itfelf, and the appropriation of crude matter neceffary for the fupport of animal life; or rather one of thefe movements is the unavoidable confequence of the other, as they neceffarily accompany and are abfolutely dependant on each other.

3. Thus the analyfis of vegetables ought not to be confined to the chemical examination of fubftances extracted from plants, and already deprived of life; it fhould be extended to the confideration of the properties of thefe fubftances contained entire in vegetables, and fharing their vital movements; it fhould inquire into the production of the feveral changes they undergo, the fucceffive ftages by which they are elaborated, and the ufes which each is deftined to fulfil in vegetable life. It is the whole of thefe facts which I term the chemical phenomena of living vegetables, and which I place at the end of the five orders of facts previoufly examined, becaufe the knowledge of thefe was calculated to lead us to the knowledge of the others.

4. Previous to the rife of the pneumatic chemiftry, fcience poffeffed no means of ftudying, or even of forming an idea of this beautiful part of phyfics. The firft experiments that were made, from thofe of Hales to thofe of Duhamel and Bonnet,

Bonnet, ſeemed to belong to knowledge of a different claſs from any thing chemiſtry could furniſh; and this ſcience, at that time too modeſt, and too much confined in its views, was employed merely in extracting, ſeparating, purifying, and preſerving the different materials of plants, and particularly in applying them to medicinal purpoſes. It was the diſcovery of elaſtic fluids, that produced a more intimate connexion between the views of chemiſtry and thoſe of vegetable phyſics; and led us to perceive, that it would be thenceforward impoſſible to ſtudy and conceive the mechaniſm of vegetation, without combining the data and the means furniſhed by chemiſtry with the experiments formerly made.

5. Accordingly from this period chemical and pneumato-chemical apparatuſſes began to be employed for ſtudying the phenomena of vegetation; for aſcertaining what it is that plants derive from earth, air, and water, what they borrow from light and heat, how the matters they abſorb afford them nutriment, and how they become vegetable compounds; in a word, in what vegetable life really conſiſts. This firſt labour opened a new and vaſt career to natural philoſophers, in which they have yet advanced but a few ſteps; a career beſet with difficulties far greater than the analyſis of dead vegetable ſubſtances. It is a rapid ſketch of theſe firſt ſteps, and of the diſcoveries to which they have led, that I range in this laſt 'der of facts.

Article II.

Of the Nutrition of Vegetables in general.

1. When we reflect on the end which chemiſtry ought to propoſe to itſelf, in explaining the yet myſterious mechaniſm of vegetation, we perceive, that the firſt and moſt important problem it has to ſolve conſiſts in determining how crude or inorganic matter, foſſil or aëriform ſubſtances, received into the veſſels of plants, there take the nature of vegetable compounds: how with ſimple ſubſtances, or binary compounds, vegetables form the matters which elongate, unfold, enlarge, and nouriſh them, increaſe their bulk, and thus give birth to all the ſucceſſive phenomena which their life exhibits.

2. To find the ſolution of this problem, it muſt firſt be obſerved, that, in moſt circumſtances of vegetation, the matters, which ſerve as the primary nouriſhment of plants, ſeem reducible almoſt to nothing, when their tenuity is compared with the ſolidity of vegetables. We know, that a number of vegetables grow on hard and ſolid ſtones, which can impart nothing to them: that ſuch is the firſt vegetation, which takes place in lichens and moſſes on quartz and granite: and that apparently the matter by which plants are nouriſhed may be brought to them

them solely and absolutely by the air, since it cannot be imagined, that the silex condensed in stones can answer this purpose

3. The same reflection may be made on plants, and even on trees, sometimes of considerable bulk, which spring up in pure sand, grow and even shoot forth deep roots in compact sand-stones, or in the clefts of lava of extreme hardness. After this we must not be astonished, to see the stones of buildings covered with vegetations, the smallness of which and their extensive surfaces announce, that the contact of air alone is sufficient for their existence.

4. But if we may conclude from this general and constant observation, that solid or pulverulent aliment is not absolutely necessary to vegetables; it is not the same with regard to light, caloric, air, and water. Too many facts here concur to leave us any doubt, that these substances, so abundant around the globe, on its surface, or in its cavities, and which nature has placed in every part, are indispensable to their existence: and that in the absence of more substantial nourishment, which the soil so frequently refuses, plants draw from these immense reservoirs of life and matter the substance requisite for their support. We must therefore separately examine the influence of each of these primitive matters on vegetation.

ARTICLE

Article III.

Of the Influence of Light on Vegetation.

1. IT is a fact long known, that vegetation is very strikingly affected by the light of the sun. Plants appear to seek it, and to turn toward the side whence it comes. It is observed on the mantlepieces, on which bulbous rooted flowers are put to grow; for these flowers incline toward the windows. It is remarked in forests, where trees are very close together: in this case the trees shoot upward, and by their vertical position seek the light one over the other, according to their vigour. Their ascent is even promoted by planting them at little distance from each other.

2. This kind of affection in vegetables for light is such, that we see plants enclosed under wooden frames which have but a few chinks, and where the air circulates underneath, incline toward the chinks, and bend down to seek the rays of light. Herbs sown in subterraneous places shoot toward the air-holes, and rise along the passages through which a portion of light is transmitted.

3. All vegetation that takes place in the shade is accompanied with phenomena, which strongly prove the influence of light. From the feeble herbs which grow beneath stones, between shady tufts

tufts of mofs, or in the fubterranean cavities of mines, to thofe which are fown for the purpofe in cellars; thefe vegetables every where exhibit a loofe, foft, and watery texture, herbaceous and flender ftalks or fhoots, without vigour, without tafte, without colour. Their fibres, drenched with fluids, and as it were œdematofe, never affume the woody character. Their tafte is always aqueous and infipid; they never become aromatic or odoriferous. They are generally called *etiolated* or blanched plants. The fame phenomenon takes place in leaves which envelope and cover one another; either by enfheathing, or by folding over one another, as in lettuces, fuccory, cardamoms, which gardeners keep clofe together by bands, and in cabbages, &c. The external leaves are very green, thofe within are white and *etiolated.*

4. On the contrary, the places where light falls more directly, the climates fituate under the equator, or near the equinoctial line, abound with hard, woody, coloured, aromatic vegetables. Thefe are the country of hard woods, of very dark and often folid leaves, of volatile oils, of refins, of the camphor principle of aromatics, of very fapid and powerfully medicinal plants, and even of the moft terrible vegetable poifons. This effect is very ftriking alfo in temperate climates, with refpect to plants growing freely in the open air, in fields where they receive the light of day on every fide, compared with others of the fame fpecies raifed by art in the fhade of under-ground places, as has been done

done with different varieties of endive and fuccory, cultivated for winter fallad.

5. This influence of light is fhown even by the effect of lamps, according to the interefting experiments of Citizen Teffier at Paris, and of Mr. Humboldt at Berlin. The latter gentleman, it is true, has proved moreover, that the contact of fome other elaftic fluids may in a certain degree fupply the place of light, and produce analogous effects, as I fhall fhow farther on: but it is not the lefs true, that the artificial light of lamps produces an action fimilar to that of natural light; and that by increafing their number, we may produce in vegetation phenomena more or lefs fimilar to thofe which are feen to be effected by the rays of the fun.

6. The caufes of this effect of light on vegetation have not yet been decidedly difcovered, or at leaft fo confirmed, that no doubt about them remains in the minds of natural philofophers. Some think that it is by a real combination with vegetable matter that it changes its nature, and that it particularly effects its combination: others affert, that its contact merely favours the decompofition of water and carbonic acid, and the fixation of the hidrogen of the one and the carbon of the other, in the vegetable compounds, and the evolution of their oxigen in a ftream of gas. We fhall fee prefently, in the fubfequent articles, the facts by which I am led to imagine the fecond opinion more pro-

 bable

bable than the firſt. Still it muſt be obſerved, that the effect of light on vegetables, to whatever cauſe it may be owing, is to warm them, to increaſe their power of ſuction, to reſiſt the ſeptic decompoſition, to colour them, to give riſe to oleaginous, aromatic and acid ſubſtances, to promote the evolution of oxigen gas, and to render vegetation in general very active.

Article IV.

Of the Influence of Air on Vegetation.

1. THE great influence of the air on vegetation is no more to be doubted than that of light; or rather even thoſe natural philoſophers, who do not conſider its influence to be ſo powerful, at leaſt admit the great neceſſity for air in this operation of nature; and in fact all the phenomena, which plants exhibit, combine to prove the utility and even neceſſity of air in vegetation. The vigour with which plants thoroughly expoſed to it puſh forth, and the languor which vegetables deprived of it diſplay, are well known.

2. It is a very certain and conſtant fact, that there is not one plant, which, if confined under a veſſel where the air is not renewed, though all other circumſtances ſhould be completely favourable to it, would not die in a longer or

ſhorter

ſhorter time, according to the quantity of this fluid allowed it: while if it be taken out of this priſon, the moment it begins to droop, and placed in the open air, or if freſh air, eſpecially oxigen gas, be let into the veſſel, it ſoon reſumes its priſtine ſtrength and vigour. This phenomenon is ſeen on a much larger ſcale, when we compare the diminutive ſtate and little growth exhibited by the ſame plant in a cloſe and confined garden, with the ſize which it acquires in a ſpacious field; the ſmallneſs of crops of corn in the neighbourhood of trees, with the abundance afforded in an open country; the difference in many vegetables growing in the depth of dark and ſhady foreſts, from the height and ſtrength they attain in an open ſituation, and on the ridges of hills or mountains.

3. But in what does this influence conſiſt, and where is the cauſe to be found? The air of the atmoſphere is a fluid that abounds with ſuch different matters, beſide the proper nature of its two component parts, oxigen gas, and azote gas, and the ſmall portion of carbonic acid gas, which it always contains, particularly with regard to the very different quantities of water, which it diſſolves according to a multitude of various circumſtances, that it is very difficult to determine by what material it is ſo eminently and indiſpenſably conducive to vegetation. Hence, this part of the problem of the phyſiology of vegetation is yet perfectly

new, and has never been ſolved. Natural philoſophers have offered different hypotheſes, the truth of which has not yet been confirmed by experience. Some have ſuppoſed, that air, penetrated into vegetables, and ſupported life in them by a kind of reſpiration, as it does in animals. Hales was inclined to this idea, from his experiment in which he had ſeen the air paſs into the ſtalks of plants, when he made a vacuum round the lower part of them incloſed in the receiver of an air-pump. But this experiment affords nothing applicable to the mechaniſm of vegetation, ſince the vacuum, which is the cauſe of this paſſage of the air, can never take place in plants. We can never find any thing in theſe that reſembles the reſpiration of animals.

4. Other natural philoſophers have ſuppoſed that the air conveys nouriſhment to plants, and that it is wholly, or almoſt wholly, derived to them from the atmoſphere; that for plants to find their nouriſhment in it, this fluid muſt always contain an equal proportion of its two elaſtic fluid principles; that when its oxigen gas, which is particularly ſubſervient to vegetation, is exhauſted, it can no longer maintain this operation, and then the plants die. As to the neceſſity of this renovation, they admit it in that of receiving a ſort of excrements, or a vegetable perſpiration, which converts its oxigen gas into carbonic acid, or in that of furniſhing by its abſorption one of the aliments of the vegetable.

getable. Both these ideas may be true at the same time. No direct or sufficiently accurate experiment has yet proved, that either of them merits our exclusive preference to the other.

5. The necessity of air to the support of vegetable life appears to depend so essentially on the presence of oxigen gas in this fluid, that, according to the experiments of Mr. Ingenhousz, plants may be made to vegetate in gases that are not respirable; particularly in azote gas and hidrogen gas, provided a certain quantity of oxigen gas be introduced into them. It appears that the oxigen gas, becoming the recipient of the carbon given out by the plants, which is one of their excrements, thus passes to the state of carbonic acid, which is capable itself of serving anew the purposes of vegetation, as I shall show in one of the following articles.

Article V.

Of the Influence of Water on Vegetation.

1. WATER is so useful to vegetation, and this utility is so apparent to all men, that the majority of natural philosophers consider it as the *primum mobile* of the growth of plants, and as the most useful of the matters that enter into their composition, from the date of the experiments

periments of Van Helmont, Boyle, and Duhamel, who made trees grow in pure water for many years; to thofe of Tillet, who has proved that the nature of the foil in which feeds germinate is almoft indifferent, and that they require fcarcely any thing for their generation but the prefence of water. All the experiments of philofophers, all the obfervations of naturalifts and hufbandmen, combine to prove the great utility of water in vegetation: and its fuperior importance to all other matters is a fact generally acknowledged, on which no doubt can arife, and the explanation of which has much engaged the attention of the learned.

2. If ftill more to confirm this primary influence, this great utility of water in vegetation, it were neceffary to add to the accurate but always confined experiments of natural philofophers effects equally conclufive by their authenticity and magnitude, experiments made on a large fcale, we might cite the fertility of places always wet, the richnefs of watered meadows, the advantage that land through which rivulets flow poffeffes over a dry and acrid foil, we might appeal to the celebrated experience of the annual inundations of the Nile, and the fertility of Egypt in confequence of this inundation, confidered by the inhabitants as the efpecial favour of Heaven. Facts borrowed from practical agriculture, and the hiftory of the productions of different countries, would furnifh irrefragable proofs of this well eftablifhed

influence

influence of water on vegetation, proofs that might even be ſtill more accumulated with advantage. Another equally ſtriking might be found in the remarkable induſtry of the gardeners who cultivate the marſhes near Paris. From theſe marſhes, ſituate all around that vaſt city, they derive great profits, they cover the ground with abundant and uninterrupted crops, and they are indebted for this almoſt aſtoniſhing ſeries of vegetable production to the enormous quantity of water, which they are inceſſantly conveying into their grounds, and the continual waterings, with which they fertilize them.

3. One important queſtion ariſes reſpecting this influence of water in vegetation: to endeavour to ſolve it, we muſt begin with obſerving in what manner it acts on the different organs of plants. There is no doubt that it paſſes through the roots; ſince a dry, withered plant erects itſelf, is refreſhed, and continues to vegetate, when its roots are put into water; ſince we ſee coloured liquors aſcend in the veſſels of young white radicles, and impregnate them with their colour; and laſtly, ſince every plant, every tree of which the roots are more or leſs watered or humectated, puſhes with more or leſs vigour, and fulfils all its functions. This water aſcends into the ſtalks, and diffuſes itſelf through all the parts of plants; it flows off or eſcapes in part by the leaves, which pour it out into the atmoſphere; and the more abundant this tranſpiration is, in conſequence of the

heat

heat and diffolving quality of the air, the more confiderable is the fuction of water by the roots.

4. It is equally indubitable, that germination is produced, if not exclufively, at leaft in part, by the help of water; fince feeds before they germinate require its abforption; fince all dry matter excludes germination; and fince moift earth, or fome wet fubftance or furface, is neceffary to occafion it. It does not appear, however, that it can take place from the action of water alone, and that feeds wholly immerfed in water can germinate: it is even imagined, that this does not take place in aquatic plants, the feeds of which fhoot out only on the furface of the water, and fome of which afterward fink in the veffel, in order to attach to it their roots. But is it only by the feeds during germination, and by the roots during vegetation, that water thus penetrates vegetables; and is there no other way, by which it introduces itfelf into plants?

5. Moft of the natural philofophers, who have employed their attention on vegetable phyfics, have thought that the leaves of plants were full of veffels and abforbent pores, by which they inhaled or fucked up from the atmofphere the water feparated from it in the ftate of dew, and that this abforption, which might fupply the place of that of the roots when the earth was dry, was carried on particularly by night, and when the dew fell. In fupport of this opinion, fome have even adduced the difference between the two furfaces of leaves, fo well obferved by Bonnet,

Bonnet, and which is fo great in their ftructure as well as functions, that, if placed on water with the lower or rough furface next to it, the leaves remain green, and vegetate; but if placed on it with the upper or fmooth furface downward, they dry and perifh, or live a much fhorter time than the others. The former furface was efteemed abforbent or inhalant, and the latter exhalant. But we do not fee how, or by what power, the water of the atmofphere can penetrate them; how it can infinuate itfelf into the veffels of plants, without repelling the fluids contained in thofe veffels, unlefs we fuppofe a vacuum; and this, we know, is not demonftrated.

6. In whatever manner, or by whatever way, water infinuates itfelf into the veffels of plants it is ftill certain that it paffes through them continually, that it penetrates all their organs and every part, that it is inceffantly renewed in them, and that this renovation and circulation are neceffary to the exiftence of vegetables, fince the ftrength and quicknefs of vegetation pretty accurately correfpond to the quantity of water abforbed. Nothing more is wanting, than to know for what purpofe water is ufeful in the nutrition of vegetables; for the growth of plants is the effect of its introduction into their interior parts, its ftay there, and its paffage through them. All that the ftate of fcience has hitherto enabled us to difcover is what follows. The water which paffes into the roots,

and is filtered through them, carries with it at firft all that it has taken from the earth, which is impregnated with it; and in this point of view it is the vehicle of all that the earth can contain for the food of plants.

7. It is at prefent fully proved, that water impregnated with air, and with fome foluble elaftic fluids, is much more ufeful to vegetation than water deftitute of air, or boiled water. Hence fnow-water, which, as the fnow gradually melts, refumes the air it had loft, and in this ftate of aëration infinuates itfelf into the earth, where it waters the roots, occafions fuch a quick and remarkable vegetation in the beginning of fpring. For the fame reafon the water of a fine and gentle rain, which, after having traverfed a portion of the atmofphere, and taken from it a confiderable quantity of air, uniformly covers and gradually penetrates the foil, in which the roots of plants are fixed, gives activity to the growth of the plants. It is remarked alfo, that when plants are watered from a well or a ciftern, their vegetation is much feebler than when the water employed for the purpofe has flowed a certain length of time in contact with the air, fo as to have been able to faturate itfelf with it.

8. The different matters capable of contributing to the nourifhment of vegetables, which are contained in the earth, are there in a dry and folid form, which does not allow them to penetrate the texture of roots, or confequently that

that of the ſtalks of plants. It is the water which conveys the molecules of different natures, that may ſerve as food to plants, either ſuſpended from being in a ſtate of minute diviſion, or as actually diſſolved by an appropriate chemical agent. Thus it is water that imparts to theſe molecules, by which vegetables are nouriſhed, that liquid form which is ſuitable to them, and without which they could never be introduced into the texture of plants. The more of this ſolvent paſſes into them, the more alimentary matter we muſt conceive to be carried with it into the organs of plants. We ſhall ſee that water can thus convey even ſiliceous earth, which is actually found in the analyſis of vegetables after the ſeparation of all the ſoluble, ſaline, inflammable, and other matters.

9. It is almoſt uſeleſs to point out that water, by inceſſantly paſſing along the veſſels of vegetables, conveying into them different ſubſtances adapted to increaſe their ſubſtance and add to their growth, diſtends, fills, ſwells, and elongates their canals; that it ſupports their parenchyma, their air-veſſels, their texture in general, in a proper degree of diſtention; and thus we readily conceive how, after a drought, a drying wind, or expoſure to the burning rays of the ſun, drooping plants, the wrinkled, bowed, and falling leaves of which threaten even to paſs into a ſtate of greater ſuffering, and to certain death, if their thirſt be not ſatisfied, riſe up, exert themſelves, diſplay their leaves in ſuch a

 degree

degree of extenſion, and with ſuch openneſs, ſpread, and colour, as are ſuitable to their exiſtence, and ſoon begin to puſh forth with more vigour than before.

10. No perſon doubts likewiſe, that water in its natural ſtate, and without decompoſition, enters as ſuch into plants for one of their conſtituent principles, and makes a part of the elements of which they are compoſed. Thus water forms the baſis of the ſap, and of all the juices found in them; thus it holds in ſolution their acids, ſalts, and extractive matter; it ſoftens their mucilages, &c. This was the only idea the ancient chemiſts had of the uſe of water in vegetation; and they carried it ſo far as to imagine, that water exiſted in a ſolid ſtate in ſeveral vegetable compounds. At preſent we have a greater opinion of its vegetative utility.

11. Since Lavoiſier and Citizen Berthollet occupied themſelves with this ſubject in 1785 and 1789, ſince Ingenhouſz diſcovered, that leaves immerſed in water, and expoſed to the ſun emitted oxigen gas, it has been imagined that water was decompoſed in the veſſels of vegetables, and particularly in thoſe of their leaves; that this decompoſition was promoted by the contact of light, eſpecially by that of the ſun; that the effect of this decompoſition was the reverſe of that which chemiſts accompliſh by means of combuſtible ſubſtances, the water depoſiting in the plants its hidrogen, which formed in part their oils, extracts, and colouring matter; that a portion

a portion of its oxigen at the fame time became fixed in them to conftitute their mucous, faccharine, feculent, and other oxides, or vegetable acids; that the greater part of this oxiding and acidifying principle, detached or feparated from the hidrogen, and diffolved by the caloric of light, affumed the form of gas, and iffued frequently with rapidity from the furface of vegetables, and particularly from their leaves, to diffufe itfelf in the atmofphere.

12. Thus in the difcovery of the decompofition of water in leaves expofed to the rays of the fun, were found at once an ingenious explanation of the great utility of this fluid in vegetation, and a fource of the two principal elements which enter into the compofition of the fubftances found in plants, among which hidrogen is well known to act the chief part; and we are enabled to conceive how nature renovates the atmofphere by a very fimple mechanifm, and imparts to it by means of vegetation, which is in this refpect a decombuftion, the oxigen that fo many caufes inceffantly combine to take from it. Thus from the knowledge of a fimple phenomenon, and of one fingle caufe, we are enabled to account for a number of complicated circumftances and facts, the exiftence of which, or their connection with natural philofophy, was not before conceived. It muft be remarked, however, that there are fome modern philofophers who deny this decompofition of water by living leaves, affifted

by expoſure to the ſun: we ſhall ſee preſently on what their denial of it is founded.

ARTICLE VI.

Of the Influence of carbonic acid Gas, and of ſome other Gaſes on Vegetation.

1. AFTER the principal diſcoveries of the differences and properties of the various ſpecies of elaſtic fluids, attempts were made to aſcertain their action and influence on vegetation. It was ſoon perceived, that no gas but common air and oxigen gas could maintain this grand phenomenon, and that in this reſpect it exhibited a very ſtriking analogy to the life of animals, and to combuſtion.

2. But it was perceived, in the courſe of theſe reſearches, that the purity of the air was far from being as indiſpenſable for the ſupport of vegetation, as for that of reſpiration; that vegetables continued to live in air too much altered or ſpoiled, to be capable of ſupporting animal life; that moſt of them even ſhoot forth more vigorouſly in an air ſomewhat impure than in very good air; and that in the latter caſe the ſpoiled air, which ſerved for this more vigorous vegetation, was perceptibly improved, at leaſt, in the firſt periods of this action,

action, instead of continuing to grow noxious, as it does in every sort of combustion, and by the respiration of animals.

3. When the last-mentioned fact, that of plants vegetating with more vigour in spoiled air than in very pure air, had been confirmed by experiments sufficiently numerous, it remained to be determined, to what this singular effect was owing; what kind of alteration in the air, so far from being injurious to vegetation, seemed to be advantageous to it; what gas, diminished or added to the atmosphere, produced this singular effect; and by what mechanism it was in reality brought about. Though this is not yet completely determined, some important facts however have been discovered in the research, which may serve at least to solve a part of the great question included in the inquiry.

4. It has been discovered, both by the analysis of air spoiled by animals and still fit for vegetation, and by the artificial composition of mixtures of airs in which plants have been set to vegetate, that this advantage to vegetation, of air previously used, was owing to a certain portion of carbonic acid, contained in it much greater quantity than in common air. Mr. Ingenhousz convinced himself, that by introducing into azote gas and into hidrogen gas, either of which alone is incapable of supporting vegetable life, a certain quantity of carbonic acid gas, they became capable of it. Mr. Humboldt has since found, that eight or ten hun-

dredth

dredth parts of carbonic acid gas, added to atmofpheric air, rendered it extremely fit for vegetation; and that fuch was fometimes the ftate of a certain part of the air of mines, where a whole clafs of crypogamia plants germinated, and fhot forth brifkly.

5. This utility of carbonic acid to vegetation, and the influence it manifeftly has on this function, are difcoverable alfo in water impregnated with it, and which is known to be much better for watering plants than common water. There is fcarcely any fubterranean water, filtered through ftrata of vegetable mould, which does not contain fome portion of carbonic acid; and this water, juft as we find with refpect to animals, not only is without danger like the pure acid gas to the fupport of vegetable life, but even contributes in an eminent degree to augment its activity, and increafe its energy.

6. The action which this acid produces, either as gas added to the air in which the plants are immerfed, or as diffolved in the water which their roots abforb, or as combined with the aqueous vapour or dew which moiftens their leaves, appears to be owing to its decompofition, which is effected in the texture itfelf of thefe laft mentioned organs, and is fhown by the experiments of Mr. Ingenhoufz and Citizen Sennebier. In this kind of decompofition, analogous to that which is effected by phofphorus heated with carbonate of foda, that of lime, &c. the carbon of the carbonic acid is feparated from

from its oxigen, and combines with hidrogen, oxigen, &c. to form the different immediate materials of plants, which we know contain these primary principles, and the greater part of its oxigen, which forms 0,72 of it, is evolved as an elaſtic fluid, mixing with the air, and meliorating it.

7. In this effect we cannot but perceive one of the ſources of the carbon that exiſts in plants, and which ſo frequently conſtitutes the greater part of the elements that compoſe them; and while this manner of explaining the mode of intromiſſion into the ducts of vegetables, gives a very ſatisfactory reaſon for the uſeful influence, that the carbonic acid gas contained in ſpoiled air has on plants, it has the advantage of enabling us to underſtand one of the moſt difficult, moſt abſtract, and moſt profoundly hidden phenomena exiſting in vegetable phyſics, that of the formation of the carbonaceous compounds, which exiſt ſo abundantly among the materials of plants.

8. It is to the ſame cauſe only we can aſcribe an effect equally remarkable produced on vegetables by carbonated hidrogen gas. This gas, when pure, kills theſe organic beings pretty quickly; but mixed in a certain proportion with atmoſpheric air, it manifeſtly increaſes its productive property in vegetation. There are even circumſtances well known by farmers, in which this gas, eſcaping from marſhes, pools, bogs, rotten dunghills, the water draining from them,

 ſtables,

ſtables, &c. and enveloping plants completely in all parts, makes them grow with great rapidity, and ſometimes even, amid this rapid growth, occaſions them to contract a ſmell and taſte, which atteſt its influence. It is too evident, to require a more minute explanation here, that this effect is owing to the ſame cauſes, and depends on the ſame theory, as the influence of carbonic acid; and that, though the action of carbonated hidrogen gas be more ſpeedy than that of the carbonic acid, it ariſes from the carbon it contains being more naked, and more diſpoſed to penetrate the veſſels of plants, than that which being united with oxigen, adheres more ſtrongly to it, and is more difficult to be ſeparated.

ARTICLE VII.

Of the Influence of the Soil, and of its Amendment, on Vegetation.

1. OBSERVING vegetables fixed in the earth, men have always been led to think, that the ſoil in which their roots were buried furniſhed the principal matter of their nouriſhment, and that they derived from this all the qualities by which they are diſtinguiſhed, Hence, the ancient notion,

tion of the connection of ſoils with their productions, which has always conſtituted one of the principal or fundamental dogmas of agriculture. The ſame ideas of the influence of the earth in favour of this or that vegetable, or giving to ſuch a plant a peculiar character, have always been propagated from ancient times to the preſent; and there is not one ſingle farmer in our days, who is not perſuaded, that plants derive from the ſoil in which they grow characters depending on it excluſively, ſuch as a particular flavour, a peculiar ſmell, &c.

2. In reality there can be no doubt, and too many examples confirm it, that the quality of ſoils is communicated to the vegetables planted in them: it conſtitutes what is called the *taſte of the ſoil.* Thus grapes, fruits, and particularly pulſe, ſtalks, leaves, and roots, acquire in marſhes a taſte, ſmell, conſiſtence, and colour, manifeſtly depending on the qualities of the earth where they have grown. This remark may be extended even to wines produced by fermentation, the reſult of a profound alteration experienced by vegetable juices: we know that they partake of the nature of the ſoil where the vine has grown, and that we may diſtinguiſh in what is called the *bouquet,* or peculiar ſmell, the difference of a dry, ſandy, ſiliceous, flinty ſoil, or too wet, too rich, and too ſtrong ground. Theſe general data, of which we cannot doubt, as well as thoſe reſpecting the particular diſpoſition of a particular ſoil to give

birth to certain productions, irrefragably prove, that every soil has a direct influence on vegetables growing in it.

3. But though this truth be well established, there is one equally certain; namely, that what are called *soils* are powders or masses very complex in their mixture and composition; and to determine with accuracy the kind of action they exert on vegetables, most of the properties of which they modify, it is necessary to inquire particularly what is owing to the earth properly so called, and what is effected by substances foreign to the earthy particles mixed with them. The first constitutes the base of the soil properly speaking, the second belong more or less to the article of manure, which will be the next on which I shall treat.

4. Among the soils in which vegetables grow, it would be vain to seek a pure and isolated earth. The finest, driest, most acrid sand, approaching nearest to siliceous earth properly so called, is always a mixture of quartz, alumine, and frequently a little calcareous matter. To determine in what manner each earthy substance contributes to vegetation, or to the support of vegetables, the chemists who first applied their science to agriculture and vegetable physics, particularly examined the manner in which seeds comport themselves in each pure earth chemically prepared; and though it follows from their experiments, that seeds germinate very well in arid earths, well washed, insipid,

and deprived of every faline particle, provided thefe earths were humectated, it is likewife fufficiently proved, that neither of them exclufively or powerfully favours vegetation. Seeds may be made to germinate alfo in metallic powders or filings, and on fponges, cotton, tow, &c. moiftened with water; but in thefe mediums vegetation does not continue long, it never reaches its full term, unlefs with delicate, weak, and fmall plants, which require but very little fubftance for their nourifhment.

5. From thefe trials, however, it has been concluded, that the foil forms no more than a fimple fupport for vegetables; that it affords a lodgment and ftay for the roots; that it merely furrounds thefe with the water and nutritious matters of which they have need, and of which it is only the receptacle; that it requires only to be very eafily permeable by the roots, to retain a fufficient quantity of water to keep them always moift, to be fufficiently divided to let the air and every part of the light pafs between its molecules, and not to be fo compact as to comprefs the radical fibrils. It can fcarcely be doubted, that a fmall portion of the earth itfelf penetrates the roots, and is conveyed into the interior of vegetables, by the abforption of which the vegetable organs are capable, and by its ftate of divifion, or even of folution in water.

6. Bergman, in his differtation on *geoponic earths*, infers from a great number of experi-

ments,

ments, that the beſt earth for the production of vegetables is a mixture of two parts of calcareous earth, one part of magneſia, four parts of alumine, and three parts of ſand. All the reſearches of the moderns have taught them, that ſalts contribute nothing to vegetation; that on the contrary there is reaſon to believe them to be always injurious to it: that pure earths alone, or mixtures of them with one another, were not fit for it; and that fertile earths loſe all their properties by the action of fire. Theſe laſt facts have been particularly obſerved by Mr. Giobert, a chemiſt, at Turin.

7. From all the experiments, which have been varied in a thouſand ways, reſpecting the relation that vegetables bear to the ſoils in which they are planted, one uniform, conſtant, and of courſe certain reſult has ariſen: this is, that of all the ſubſtances found in the mixture of earths, that conſtitute a ſoil, calcareous earth contributes moſt certainly to its fertilization. There is nothing equivocal, uncertain, or contradictory in this fact. It is aſcribed to this, that moſt of theſe calcareous ſubſtances retain ſomething of their ancient animal origin, which becomes a ſort of manure. For my own part I have no doubt, that this fertility muſt be attributed to its carbonic acid. Be this as it may, it is ſo true, that calcareous matter is the moſt uſeful of all earthy or ſaline-earthy ſubſtances in agriculture, that farmers frequently renew their land with it,

8. It

8. It is neceſſary to mention, however, that though calcareous earth is the moſt frequent and moſt uſeful ſubſtance that can be employed for improving land, and on this account marle claims the firſt rank even among manures, the art of improving lands, conſidered in its greateſt latitude, cannot be confined to a ſingle proceſs, but muſt vary according to the nature of the ſoil on which the farmer is to operate. Marle and chalk are certainly ſuitable to a ſtrong and too clayey ground; but land too uniformly calcareous or ſandy may require, on the contrary, clay to give it the binding quality it wants, and the property of not drying too quickly, but retaining the water a little longer than it did before.

Article VIII.

Of the Influence of Manure on Vegetation.

1. IT has been proved above, that pure and iſolated earths do not directly ſerve for vegetation; that water alone can anſwer the purpoſe ſtrictly ſpeaking, but that it does not furniſh all the principles neceſſary for fertility and the complete growth of plants; ſo that, for inſtance, moſt afford no fruit, or at leaſt their vegetation is feeble. Though it has long been ſuppoſed, that

that plants are nouriſhed by means of their leaves, and derive their aliment from the air, ſo that they appear capable of growing by means of water, light, heat, oxigen gas, and the elaſtic fluids that uſually compoſe the atmoſphere, it is equally ſeen, by all the data and experiments of agriculture, that the greater part of the nouriſhment of vegetables is derived from the earth, and that the earth greatly influences their condition, ſtrength, quickneſs of growth, the nature, taſte, and ſmell of their fruits, &c.

2. It has long been obſerved, that the earth, in affording vegetables the principles neceſſary for their growth, is exhauſted at the end of ſome time, and that it is neceſſary to reſtore to it what it has loſt. Hence it has been inferred, that ſomething paſſed from the earth into the plants, and that this portion neceſſary to vegetation was gradually diſſipated, ſo that we were obliged to reſtore it to the ſoil. It is this addition of nutritious and vegetative matter to the earth which is called *manure*. Nature itſelf furniſhes the example of this neceſſity of continually repairing the loſs the ſoil ſuffers from the vegetables that penetrate and cover it: every year it reſtores to it what the plants abſorb by the remains of thoſe which die, accumulate on the ground, putrify there, are decompoſed, and thus form ſucceſſive layers of a ſort of mould, or vegetable earth, in which germes unfold themſelves kindly, and roots imbibe the principle of vegetable nutrition.

3. It

3. It is by this natural mechanifm, that ground crowded with trees and vegetables of different kinds growing every where around them, becomes covered to a greater or lefs depth with vegetable earth, which long fecures its fertility It is this layer of fertile mould, which men find after clearing ancient forefts, and in which they fcatter the feeds and germes of various plants, which acquire in it a quick and fpeedy growth. Thus in a fucceffion of ages are formed thofe lands of inexhauftible fertility, which man takes from the hands of Nature in the forefts of America; where he begins by cutting down or confuming the ancient vegetable inhabitants, before he enters upon the ufeful cultivation of many plants, to which our cold or temperate climates are incapable of affording nourifhment.

4. The farmer imitates this procefs of nature, when land appears to him exhaufted of its nutritious juices, by too long or too vigorous vegetation: ftirring it up with the plough, or fome other inftrument, he likewife adds to it the remains of vegetable or animal fubftances, which are called *manure*. Moft commonly thefe remains confift of the ftraw which has been ufed as litter for animals, and which, impregnated with their excrement and urine, is laid in heaps to heat, ferment, putrefy, diminifh in bulk, and become what is called dung. The leaves of trees heaped up in a fimilar manner, watered, heated, fermented, foftened, and decompofed, are likewife ufed

ufed for the fame purpofe. The bones of animals, the horny parts, and even the hardeft horns, cut into fhreds or fragments, or ground to powder, are alfo ufed frequently for manure in fome countries. In feveral, human excrements long kept, and fometimes converted into a dry inodorous matter, known by the name of *poudrette*, is employed for this purpofe.

5. It is with the fame defign, but conducted on a much larger fcale, and of more immediate utility, that intelligent men, when breaking up large quantities of ground, keep on the exhaufted or merely impoverifhed land a number of animals, particularly fheep; which, while they ftill find on it food fufficient for their wants, render immediately to the earth, either by the folid and liquid excrements which they depofit on it, or by the perfpirable matter which iffues from them when they lie down, more than they have borrowed from it. This mode of dunging ground indeed requires a confiderable capital, as the firft expenfe is great; but it amply repays the farmer who practifes it, and whofe fpeculation turns entirely, as has been feen, on the reciprocal converfion of vegetable matter into animal fubftance, and of the latter into the former.

6. The fcience of phyfics has long been filent on the mechanifm or caufe of action of manure. Ancient chemiftry explained it by a theory of falts and ftimulants, which modern difcoveries have difmiffed to the realms of fable and error.

It

It is particularly in the latter that this theory is placed by modern agricultural experiments, the refult of which has proved, that real falt mixed with the earth injures the production of plants cultivated in it. Pneumato-chemical analyfes have furnifhed more accurate notions of the influence of manure, in teaching us that plants are formed of hidrogen, carbon, oxigen, and fometimes azote, fulphur, and phofphorus, without reckoning lime, filex, and pot-afh. If thefe principles alone exift in the fubftances of plants, it is evident that they require only thefe for their growth.

7. This reafon is fufficient, to lead us to a knowledge of the action of manure. In fact, in the compound fubftances which form them we find thefe firft principles in abundance: hidrogen is contained in them fo plentifully, that it frequently efcapes in the form of gas during their decompofition. The carbon fhows itfelf in them by the black colour, which dung affumes when completely rotten, and in the hue of the mould into which it is changed. The liquor that drains from dunghills, if we abftract from it in imagination the ammonia, and the animal fubftances which are mixed with it as foreign matter, is for the moft part nothing but water holding in folution carbon, which we may fee fubfide to the bottom by keeping it fome time. Carbonic acid gas is perpetually flying off from mould; fo that nothing is wanting to this compound, neceffary to fupply nourifhment to plants;

plants; but on the contrary, the nutritious matter they afford is ſo abundant, that it is eaſy hence to explain how vegetation is ſo ſtrong in it, and the growth of plants ſo rapid.

8. We may even judge from this, and from comparing the influence of the ſoil with that of the air for the quickneſs of the growth of plants, and the vigour of vegetation, that the ſoil contributes much to it through the means of the manure with which it is covered, and that roots ſuck up with great energy the different alimentary matters in a liquid form, while very little paſſes through the leaves, which are rather organs of perſpiration. It is no leſs accurately proved to the obſerving eye, that water is the common vehicle of earths, carbonic acid, carbon, and hidrogen, almoſt iſolated, which are conveyed into the organs of plants: that for this reaſon its preſence is ſo neceſſary in the earth into which roots penetrate, and that in this it acts the double part of promoting the flow and ſucceſſive decompoſition of the vegetable ſubſtances that form manure, with a ſort of diſſection of their parts, and of conveying theſe into the abſorbent veſſels of plants.

9. Manures, or the organic matters which form them by the mixture of their particles with thoſe of earths properly ſo called, have alſo another effect beſide that of furniſhing the roots of plants with aliment: or rather this principal effect is accompanied by another auxiliary,

auxiliary, it is true, but not lefs ufeful. Thefe manures we know undergo a continual fermentation, which attenuates, divides, and decompofes them. This action cannot take place without an increafe of temperature, and the heat thus produced muft greatly promote vegetation. The earths, very rich in nutritious principles, which are employed in the beds and hot-houfes of kitchen and botanic gardens, earths which contain much horfe-dung, or tan, are fo hot, that on thrufting the hand into them, we find a great difference between the temperature without this folid medium, and that within it. Accordingly, many feeds are brought to germinate in them, which will not in our natural foil; and a great many plants are cultivated in them, which would languifh or die in common ground. Farmers know, that by ufing dung not properly rotted, or too little fermented, it occafions a too hafty vegetation, dangerous in our climates, where cold fo eafily affects or kills delicate plants raifed too foon. There is no other reafon for their carefully avoiding the ufe of too frefh and too ftrong dung, but the violent heat it occafions in the earth by the fermentation it undergoes: and thus with good caufe they term it *too hot*. It is fo true that manures ferment ftrongly, that at a certain period we obtain from them alkaline, calcareous, and ammoniacal acetites by lixiviation, and a ftrong fmell of vinegar is emitted by them, if we pour on them more potent acids.

10. There

10. There is ſtill one more effect to be obſerved in manures, which was diſcovered by Dr. Ingenhouſz: the power which they appear to exerciſe on the atmoſphere, the abſorption of its oxigen which they effect, and the tranſmiſſion of it from them into the abſorbent veſſels of the roots, which unqueſtionably takes place. If a vegetable mould be expoſed to the contact of air in a cloſe apparatus, when we examine this air ſome time after, we ſhall find it deprived of a portion of its oxigen. This privation ſoon proceeds to a total abſence of it, ſo that it is one of the ſureſt means at preſent of procuring atmoſpheric azote gas. Though Mr. Humboldt believes that he has obſerved this abſorbent property in pure earths, and particularly in alumine and magneſia, there is ſcarce a doubt but it muſt be much more powerful in thoſe which are mixed with vegetable matters; and that theſe, conſtituting manure, act with regard to the oxigen of the atmoſphere as a ſort of combuſtibles that have great tendency to oxide, and from which roots take this principle, when they have been conveyed into their veſſels by means of water.

11. It cannot be queſtioned that this oxigen, precipitated from the air, and fixed in manures, acts a more or leſs important part in vegetation, when it is conſidered as calculated to convert the carbon of manures into carbonic acid, ſo beneficial to the growth of plants when water offers it to them in a diſſolved and fluid

ſtate;

ſtate; and when, on the other hand, we obſerve the effect produced on the nutrition of vegetables by lixivia of oxigenated muriatic acid mixed with the earth into which roots penetrate. Citizen Pajot-Deſcharmes, who ſucceſsfully applies the phenomena of chemiſtry to manufacturing proceſſes, has remarked, that lixivia of oxigenated muriatic acid, extremely dilute it is true, and which had already been employed in ſeveral operations, being thrown on the earth of a garden, ſingularly promoted the growth of the vegetables that occupied the ſpots thus watered. On comparing this obſervation with the facts obſerved by Dr. Ingenhouſz and Mr. Humboldt, we ſee clearly, that the abſorption of oxigen is one of the moſt fecundating and moſt uſeful effects of manure.

12. From theſe data, ſo much enlarged and ſo well explained by modern chemical ſcience, ariſes a knowledge of the effects produced by tilling and breaking the earth, ſo much recommended by all able huſbandmen: we ſee, that by ſtirring the earth to a certain depth, it is not only rendered lighter, ſofter, more divided, more permeable, and the weeds and inſects which live in it and exhauſt it, are deſtroyed; but the manure deeply buried is brought to the ſurface; this valuable aliment is diſtributed equally to all parts where the roots will creep; and what the preceding vegetation had taken from the exhauſted portions is reſtored to them. By thus renewing all the ſurfaces of the mould, tillage

tillage expofes to the air the matter that tends to deoxigenate it; and by increafing the abforption of oxigen by the foil, it augments its vegetative power in a degree proportionate to the renovation of furface: in a word, it increafes this concealed combuftion in which great part of the influence of the air confifts, which was formerly explained in fuch a vague manner by the falts that were fuppofed to be depofited in the earth; at a period from which we are not yet far diftant, when phyfics, in a ftate of little advancement, and contenting itfelf with thofe hypothetic gleams, which then conftituted the whole of its theory, had not acquired that accurate knowledge of the nature of the air, and the compofition of vegetable matter, which it poffeffes at prefent.

Article IX.

Of the Functions of Vegetables, or the Phenomena which they exhibit during their Life, and of the Mechanifm by which the conftituent or component Parts are formed.

1. WHAT has been faid in the eight preceding articles prefents a feries of facts refpecting all the materials, that serve for the formation of vegetables, which actually change into

into their proper ſubſtance, and which they are capable of converting into ternary or quaternary compounds, and of appropriating ſo as to increaſe their own bulk. It remains for me to give a ſketch of the manner in which theſe different elements, admitted into the veſſels of plants, are there decompoſed, or combined in a new order, by what powers they are converted into the materials of vegetables, what phenomena accompany and indicate this converſion; in a word, in what vegetable life conſiſts: for it is very evident, that a germe being given, the life it receives, and which continues till all the phenomena that conſtitute vegetation have been completely exerted, conſiſts wholly in this appropriation, this converſion, this complicated combination, which the primary materials undergo after they are received into the veſſels of plants.

2. This beautiful mechaniſm, which is called *vegetation*, has at all times excited the admiration of philoſophers, and they have endeavoured to form a conception of its cauſes, and aſcertain their effects; but their endeavours have not yet been crowned with a ſucceſs anſwerable to their wiſhes. Modern chemiſtry has revived their hopes, new paths have been ſtruck out by it, and the ſketch I am about to trace will ſhow, that the new career opened by its means, and its method, though yet little followed, have already removed ſeveral difficulties hitherto deemed inſurmountable. It is neceſſary to

 conceive

conceive in the firſt place, that the phenomena of vegetable life ſo manifeſtly belong to a chemical power, that no ſcience but that can explain its mechaniſm. This truth is included in the enunciation of the problem of vegetation. In reality it may be conſidered as the only queſtion, to determine how vegetable machines convert the principles they abſorb as aliments into what we have called their materials.

3. There is no room to doubt, that plants form theſe compounds in executing the functions, which taken together, truly repreſent the circle of their life: we muſt inquire then wherein theſe functions conſiſt, and examine their relation to the formation of vegetable compounds. The functions of vegetables are either internal, ſometimes not very perceptible, ſo that their exiſtence is known, and their phenomena ſtudied, only by the help of experiments and methods which in ſome degree aſſiſt the weakneſs of our organs, or they are external, come under the cognizance of our ſenſes, and diſplay themſelves by phenomena, or ſigns more or leſs ſtriking, more or leſs eaſy to be perceived.

Of theſe functions ſome are exerciſed during the whole life of the plant: others are periodical, or ſhow themſelves only at different ages of the plant, which are moſt commonly even determined by them. We find in ſucceſſion, and in the order in which they are mentioned,

a. The motion of the ſap, and of the fluids;
b. Their ſecretion;
c. Irritability, or the movement of the ſolids;
d. Nutrition;
e. The flowing of different juices;
f. Vegetable tranſpirations.
g. The direction of the parts of plants:
h. The periodical repoſe, or ſleep of plants;
i. The germination of plants:
k. Their foliation;
l. Their flowering;
m. Their fructification.

Some phyſiologiſts have reckoned a greater number of phenomena among the functions of plants, becauſe they have conſidered them with the eye of the agriculturiſt, &c.; but the twelve that I have mentioned compriſe in reality all that paſſes in the circle of vegetation, and every thing likewiſe that enters into the relation I mean to point out between the chemical analyſis of vegetables and the life of plants.

I ſhall proceed briefly to run through each of theſe functions, of which I have already ſaid a few words at the commencement of this ſection, but I deſcribed them only as phenonema of vegetable life; and I have here to conſider them in their mechaniſm and intimate reſults, to ſhow, that they either ariſe from chemical attractions, or lead to them.

A. *Motion of the Sap.*

4. The motion of the ſap takes place from the root toward the ſummit of the ſtem; and this fluid, manifeſtly formed by the water, which the roots have abſorbed, and which holds in ſolution the materials of the earth or of the ſoil, undergoes during this very motion certain chemical changes. With the ſap there circulates a more or leſs conſiderable portion of carbonic acid, which, by the internal heat of the plant, is frequently diſengaged from the water, and moves in the air-veſſels ſo as to iſſue with a perceptible ebullition through openings or auger-holes made in a tree. The exceſs of this acid eſcapes by vegetable tranſpiration: a great part is decompoſed, and furniſhes carbon, which unites with the hidrogen and oxigen; hence the mucilages, the ſaccharine ſubſtance, the tannin, the acids diſſolved in the ſap; hence too the extractive matter, which ſometimes colours it, and renders it always liable to become coloured by the oxigen of the atmoſphere. Frequently this nutritious juice carries with it ſalts, and even acetites, which the water has taken from the manure uſed on the ground, as well as earths and carbon in a ſtate of minute diviſion, proceeding from the ſame ſource.

5. Many hypotheſes have been framed, to explain the mechaniſm of this aſcent of the ſap.

ſap. The following is the moſt ſimple, with the greateſt appearance of probability. The warmth of ſpring, which excites it, dilates plants, and recalls their life, which the winter's cold had benumbed. The diluted veſſels have a vacuum produced in them, which cauſes the aſcent of the fluid that remained in the ſtem, and was collected in the roots; and in ſucceſſion that which moiſtens the earth, in which the roots are embedded. This firſt movement of vegetation does not ſlacken or ſtop, but with the diminution of the temperature of the atmoſphere to a few degrees only above and below 0. Whether the ſap re-deſcend toward the earth by the cortical layers, and whether this paſſage be open to it only during the night, are problems that remain to be ſolved: though they have been conſidered as decided by cicatrices and the ſwellings that grafts form above the ſtock, and by the iſſuing of the ſap from the upper end of a notch. The ſap, carried at firſt toward the centre of the ſtem, ſpreads laterally and along the prolongations of the pith, to reach the external layers, where the dilatations and vacuums are greater. The lighteſt, moſt fluid, moſt rarefied portion of the ſap, and the moſt remote from the roots, after it has depoſited the matter capable of becoming ſolid, which it held in ſolution, iſſues through the leaves in vapour or in drops. We learn from Hales, that the power of aſcent in the ſap of the vine reaches to thirteen metres, conſe-

quently

quently higher than water is ſupported by the weight of the atmoſphere.

6. We readily conceive, that this aſcending and lateral motion of the ſap, and of the carbonic acid gas, or of the air with which it may equally be accompanied, muſt exiſt in the different fluids of vegetables, which are known by the name of their *proper juices*; but that this ſecond ſort of motion is but a ſlow and limited change of place, compared with that of the ſap, on account of the leſs abundance of theſe juices, of their diſtribution in particular orders of veſſels, of their adheſion which is proportional to their greater conſiſtence, and of their more intimate propenſity to grow thick, concrete, and become ſolid. Theſe juices have ſcarcely any thing more than the ſlight motion, which the ſap communicates to them, and is produced by its lateral preſſure on them. Thus we ſee it would be an abuſe of words, and an entire confuſion of ideas, to compare theſe movements of vegetable juices with the circulation of the blood in animals.

B. *Secretion.*

7. WHEN the ſap, the primary nutricious fluid of vegetables, water loaded with all the matters which it has taken from the ſoil more or leſs manured, has arrived at the different parts of the vegetable, which envelope the common veſſels, it diſtributes itſelf to the different orders

of

of its texture, which it traverſes, or with which it is in contact: and it depoſits in them the ſubſtance proper for enlarging the growth of each, or for repairing the continual loſſes it ſuſtains. In this ſeparation, in this diviſion of the different materials, all contained in the ſap, but appropriate to each of the veſicular organs in which they are depoſited, conſiſts ſecretion, the exiſtence of which in the phenomena of vegetation cannot be overlooked, or its influence in them denied.

8. Undoubtedly we do not yet well know what the mechaniſm is, by which the ſap, that appears in the veſſels as a homogeneous fluid, yields different juices to different parts, and is converted into matters frequently the reverſe of each other. The fact however being acknowledged as certain, it appears, that we can admit as the cauſe of this converſion nothing but a true chemical change, governed unqueſtionably by the ſtructure of each order of cells, their diſtance from the centre of the tree, their propinquity to the ſurface expoſed to the air, and the difference of temperature. We may form ſome idea of this chemical function, by ſeeing all the homogeneous vegetable ſubſtances, when operated upon in the laboratory by fire, by the nitric, oxigenated, muriatic, and ſulphuric acids, and by cauſtic alkalis, ſeparated into two or three new ſubſtances different from each other, namely, into two acids, into oleaginous ſubſtances, &c. I have no doubt but a chemical

chemical action, perfectly similar to that I have mentioned, takes place in the operation of vegetable secretion. The carbonic acid, oxigen gas, and the influence of light and caloric, to which the sap is more or less exposed in the little bladders or cells where it stays, are probably the agents in these chemical operations, the whole of which are comprised in the function of secretion.

9. It is thus I conceive the successive formation of all the proper juices, the gummy, saccharine, oily, acerb, colouring, and acid; as well as that of the solid parts to which they give birth by their concretion, as the woody substance, the fecula, the tannin, the resins, the concrete salts, &c. Thus by the action of chemical powers, which seize on different part of the sap, are composed the substances I have examined under the name of *immediate materials of vegetables:* thus are deposited in the roots, stems, leaves, flowers, fruits, and seeds, the different matters that form them. We may see a slight sketch of this in the spontaneous alterations the sap undergoes, as it exudes naturally in tears, or is extracted by boring holes in the trunks of trees, when exposed to the air, the contact of which colours it, renders it turbid, precipitates it, alcoholizes it, sours it, &c.

C. *Irrita-*

C. *Irritability.*

10. Little connection appears at firſt between the function termed *vegetable irritability*, and the chemical properties of which I here eſtabliſh the exiſtence in the cauſes and phenomena of vegetation. We are indebted to modern philoſophers for the admiſſion of vegetable irritability. On ſeeing the leaves of the ſenſitive plant ſo moveable at the ſlighteſt touch, the ſudden motions of the flower of *dionæa muſcipula*, the contractile drooping of the foliage of the *Ledyſarum gyrans*, the almoſt convulſive contraction of the ſtamens of the common berberry, and of the dwarf ciſtus when irritated by a pointed inſtrument, and ſo many other motions which ſeem to contract the muſcles of the parts of plants in which they are obſerved, the moderns have imagined, that an irritable power, ſimilar to that of the organs of muſcular motion in animals, exiſts in theſe parts.

11. Mr. Humboldt, while carefully ſtudying this beautiful vegetable phenomenon, has inquired into its connection with ſome chemical power or cauſe: and he has found ſubſtances that increaſe it, that renew it when it is weakened, and others that diminiſh it, or cauſe it to ceaſe. In general, oxigenated ſubſtances that eaſily part with their oxigen appear apt to produce

woody layers, the mucilage in the cortical layers and under the coverings of the seeds, the acids in the leaves, and in the pulp of fruits, &c. We know not yet, it is true, by what chemical law each of these matters assumes its peculiar composition in this or that region, in this or that organ of vegetables; but it is very natural, that in the commencement of a science we should have but few ideas concerning an object so new. I have already said above, that every kind of organ having a different texture, its position with respect to the surrounding air, its distance from the centre or nearness to it, its temperature, the action of the air and carbonic acid gas within, the place even which the sap occupies relatively to the point from which it proceeded, and to the alterations it has already undergone since it was first formed, furnish the modern theory with sufficient data, to allow it at least to look forward to the period, when possessed of experiments and researches founded on the new views it suggests, it will be capable of giving a simple and luminous explanation of what appears yet a mystery.

14. Though the mechanism of the particular formation of the different materials of vegetables be still covered with a thick veil, chemistry already offers some tolerably accurate results respecting the growth and nutrition of plants, owing to the successive changes of these materials. It no longer contents itself, as heretofore,

fore, with reprefenting this growth under the vague and almoft unmeaning afpect of the condenfation and folidification of fluids; it fhows the fap, become a proper juice of the plant carried by the prolongations of the pith even to the infide of the bark, increafe on the one hand the thicknefs of the cortical layers by fucceffive additions of matter condenfing there; and on the other hand confolidate the cortical layers that were formed the laft, by means of their vifcofity, denfity, and vegetable plafticity, which it has acquired. It proves, that this confolidation is owing to the flightly hidrogenated particles of the carbon being brought clofer together, owing to the fixation of the oxigen. It fhows that a variation in the proportion of one or other of thefe principles, and of the earth and foffil falts which accompany them, forms tannin, the colouring matter, and the extractive matter, at the fame time with the wood. It points out the mucous fubftance, the faccharine matter, the amylaceous fecula, diluted at firft in an aqueous fluid, which keeps them in the ftate of mucilage, of fluid honey, of milk more or lefs thick, acquiring their folid form by the evaporation of the water, owing to the air, or to the fuction of numerous mouths, which convey the fuperfluous aquofity to the interior and tranfpiratory pores with which the leaves are perforated. It teaches us that the fuberal fubftance, which forms the inorganic and frequently papyraceous texture of the bark, acquires its dry

fragility,

fragility, or elaſtic ſuppleneſs and ſemi-tranſparency, by the exſiccation of a viſcous juice ſpread in thin coats over the exterior part of the vegetable, and modified by the contact of the air, and the action of caloric and light. It explains how a volatile or a fixed oil expelled out of plants, and thus having its ſurface expoſed to the air, becomes the firſt a reſin by loſing hidrogen, the ſecond a wax by abſorbing oxigen. In a word, it begins to penetrate much farther into the explanation of the different phenomena relating to the growth and nutrition of plants, than we could have dared to hope a few years ago; and it preſages what it may ſome day accompliſh in this elegant and uſeful branch of human knowledge.

E. *Efflux or Flow.*

15. I employ the word *flow*, to expreſs the ſpontaneous iſſue of fluids from the ſurfaces of vegetables. This is properly a vegetable ſecretion. Thus we ſee the very liquid and almoſt aqueous ſap flow from the extremities of the branches and from the joints of the vine, the birch, &c. the inſipid and gummy mucilage from fiſſures in the bark and in the ſtalks of the fruit of the almond, peach, apricot, plumb, and all other trees that bear fruits with ſtones in them; the volatile oily juice or reſinous eſſence from firs, larches, and all the evergreen and reſinous trees; the honeyed

honeyed and faccharine juice from the bottom of the petals and in the nectaries of a great number of flowers, and from the upper furface of the leaves of the afh, elm, and linden. Some glutinous juices, gummy-refinous, or of the nature of glue, flow likewife, and fpread in glutinous coats over the youg fhoots of the *acacia vifcofa*, &c. Finally, the fixed oil itfelf exudes in little fubtle drops, and appears on the furface of feveral fruits, particularly thofe of the myricas, crotons, and fome trees of the laurus family: in the air it gradually affumes the characters of wax.

16. In thefe different kinds of flowing we feeing manifeftly the product of too great fulnefs, of a plethora which fwells and tears the veffels, or which diftends and opens the cells, or which iffues from the extremities of the full ducts: it is an evacuation occafioned by the fuper-abundance of the alimentary fap, or of the proper juices of the plant. In the latter cafe it anfwers the place of a certain morbid and almoft critical flux, which is of great utility to the plants in which it occurs. The refult of this fecretion is the iffue of fome of the immediate materials of vegetables, fimilar to thofe that are extracted either by mechanical means, or by chemical proceffes. It fhows that art, in the operations it employs to procure thefe matters, makes them undergo no alteration, obtains them fuch as they exifted in the plant,

plant, and may depend as much on the products it acquires, as on those which nature furnishes.

17. I have elsewhere shown, that man imitates this process of nature by wounding or piercing plants and trees, and thus increasing the flow of matters, which are of great use by their properties in the arts. Thus are procured the saccharine juice of the maple, the sugar-cane, the palm-tree, the resinous oil of pines and firs, the gummy-resinous juice of a number of plants, particularly the umbelliferous, the extracto-resinous juice of the poppy, the euphorbiums, &c. It is by a similar mechanism, too, that the puncture of a great number of insects, which raise up the epidermis of the leaves, petióles, and stems of several trees, occasions an artificial cavity, which is filled with many different juices, and particularly with the astringent and very concrescible fluid from which we obtain the gallic acid, &c. Frequently, indeed, in the latter case, an animal matter afforded by the insects, that of their excuræ, eggs, and excrements, mixes with the vegetable substance, and modifies the characters as well as the chemical properties of the parenchyma of the galls produced by these punctures.

F. *Transpiration.*

18. Though there are yet many facts to be verified or discovered respecting the transpiration of vegetables, it is one of their functions that

that is beſt known, and that throws the moſt light on vegetation. Woodward, Hales, Bonnet, Duhamel, St. Martin of Vienna, and Citizen Sennebier of Geneva, have ſtudied it with particular care, and with very diſtinguiſhed ſagacity. Their reſults, without having that preciſe ſimilarity which it is impoſſible to find in ſuch a delicate part of phyſics, are yet ſufficiently alike on the whole, to leave no reaſonable doubt of the truths which theſe authors have recorded in their works. By giving an account of the principal reſults we ſhall ſhow, that they are well adapted to agree with the data of modern chemiſtry, which furniſhes a luminous explanation of them.

19. It has long been known, that if a living plant, or a branch of one, be encloſed under a receiver, the ſides of the veſſel will be covered with little drops of an aqueous vapour, while the plant loſes a portion of its weight. A plant deprived of life, indeed, exhibits part of this phenomenon, but with two differences: the firſt is, that in proportion as the water iſſues in vapour from its ſurface, it dries and withers, while the living plant retains its life and freſhneſs: the ſecond, that the latter continues to furniſh this aqueous product, while the dead vegetable is very ſpeedily exhauſted, and affords it only for a time, which is terminated by its becoming dry. Thus we ſee, that in the latter caſe it is a ſimple evaporation, owing to a remnant of life, and more particularly to the

ſolvent action of the ſurrounding air: while in the living vegetable there is an internal action that ſupports this function, to which the external air contributes only but for one part of the phenomena, which will be ſoon appreciated.

20. The tranſpiration of a vegetable may be meaſured, and its products collected, if the tranſpiring plant be incloſed in a glaſs veſſel. Thus Hales found that a ſun-flower, near a metre in height, loſt near a kilogramme of tranſpiration in twelve hours, and tranſpired ſeventeen times as much as a man. The moiſture of the earth in which the plant grows contributes much to the ſupport of this function: the more water the earth contains, the more iſſues from the ſurface of the vegetable. The extent of this ſurface too has much influence on it: and as it is by its leaves alone, that this tranſpiration takes place, it is evident, that the ſpace they occupy ſhould be meaſured, to compare its proportion with the quantity of the evacuation. The meaſures of theſe two will always be found in a direct ratio to each other. If the leaves of a vegetable therefore be plucked off, its vegetation will be extremely diminiſhed, by ſtopping its tranſpiration, and this may be carried ſo far as to kill the plant. We ſee here, that the principal uſe of the leaves is the exerciſe of this function, and that their multiplicity ſhows the importance of tranſpiration to a vegetable.

21. There

21. There is a direct relation between the transſpiration of a plant, and the ſuction of its roots. One of theſe phenomena follows the other ſo exactly, that there is reaſon to preſume that they are mutually dependant on each other, and that the mechaniſm of the motion of the ſap in plants very regularly follows this mutual relation of the two functions. It is tranſpiration, which carrying off into the air, under the form of vapour, the greater part of the water that flows from the trunk into the boughs, from thoſe into the branches, and from the branches into the expanſion of the leaves, is continually emptying the veſſels of the plant, and inceſſantly drawing into it freſh fluid, to replace what is evaporated. Hales found by his ingenious experiments, that the ſurface of the leaves being eleven times as much as that of the roots, the water muſt flow eleven times as quick in the roots as in the leaves.

22. The contact of light, and that of warm air, are neceſſary to keep up vegetable tranſpiration. If the former be intercepted, according to the experiments of Citizen Sennebier, by a piece of linen or paper, the tranſpiration is conſiderably diminiſhed: warm and dry winds ſingularly promote it: during the night it ſcarcely takes place. It is even found, that in the night plants increaſe in weight, and imbibe the water precipitated from the atmoſphere. It is moſt powerful in the ſpring, and at the beginning of ſummer. In autumn the leaves

becoming hard, dry, and ready to fall, no longer exercife this function: and at this period too its utility is leaft effential, fince the plant has by this time fulfilled at leaft its annual deftination.

23. On comparing the quantity of water which iffues by tranfpiration with what enters by the roots, we find very little is left behind in the plant: yet the portion that remains is fufficient for its nourifhment, and diftributes itfelf, either by becoming fixed without decompofition in the immediate materials which it dilutes, or by decompofing itfelf fo as to furnifh the hidrogen neceffary for the compofition of thefe materials, particularly the oily juices, and the oxigen proper for converting the greater part of thefe materials to the ftate of oxides or acids. A third ufe of this water in the portion that evaporates is, to leave in the vegetables through which it paffes the greater part of the earths, falts, and different matters, which it conveys from manures into the interior parts of plants: for we may conceive, that, as it efcapes in the form of vapour, it comports itfelf with regard to the principles it held in folution, precifely as the water that evaporates in chemical proceffes.

24. The water which iffues in vapour from the furface of leaves. and which forms a part of their tranfpiration, is not precifely pure water, as is teftified by the fmell of the plants, which it carries out of their texture. Citizen Sennebier fatisfied himfelf by collecting feveral

4 kilogrammes

kilogrammes in fuitable apparatufes, and evaporating what he thus collected, that it contained fome particles of extracto-refinous matter, of carbonate of lime, and of fulphate of lime; and he detected thefe four fubftances by the fucceffive action of water, alcohol, and acids, on the refiduum left by his evaporation. It appears, too, that a fmall portion of faccharine or honey matter is carried away by this water of tranfpiration; and that to this fmall portion is owing that flight, greyifh, fweet coat, which covers leaves after great tranfpiration, and which is known by the name of *honey-dew*. Sometimes it is fo copious, that it forms a duft in the air round trees that have experienced this exceffive tranfpiration in the great heats at the commencement of fummer.

25. Mr. Hedwig, in his cryptogamic phyfiology, has defcribed the veffels of the leaves which afford a paffage to the tranfpiration. They are placed under the epidermis of the leaves, and there form a net-work, the mefhes of which are very vifible, when the moift epidermis is examined with a microfcope. He thinks that feveral of thefe veffels, to the number of four or five, open into each round or oval pore, with which he afferts the epidermis is perforated. But Citizen Sauffure, who has examined the epidermis of leaves with great minutenefs, was never able to perceive the pores mentioned by Mr. Hedwig. There is reafon to believe, that, inftead of having holes, the epidermis dips into the cavi-

ties

ties of the tranſpiratory veſſels. With a good lens we may ſee pretty diſtinctly the extremities of theſe veſſels, which form little prominences, or a kind of circular tubercles, on the upper ſurface of leaves.

26. The tranſpiration or inviſible vapour, which iſſues from the leaves, and forms ſuch a conſiderable evacuation or excretion of vegetables, does not conſiſt ſolely in the water of which I have hitherto been ſpeaking. Part of this vapour conſiſts of oxigen gas, ariſing evidently either from water, or from carbonic acid, or perhaps from both together, decompoſed in the plant. The iſſue of this gas is one of the chief requiſites of the mechaniſm of vegetation: it announces, and no doubt produces, the health and vigour of plants. It diffuſes throughout the atmoſphere, which it perpetually renovates, the portion of oxigen gas, deſtined inceſſantly to compenſate what is abſorbed in the numerous combuſtions that take place in the ſurface of the globe. It is particularly the iſſue of this gas, united perhaps with the watery vapour of tranſpiration, that requires the contact of light already mentioned above as ſo favourable to tranſpiration. At the ſame time there iſſues from plants, or at leaſt is formed immediately on their tranſpiring ſurface, a pretty conſiderable quantity of carbonic acid gas. It may be obſerved here, that theſe three materials of vegetable tranſpiration, water, carbonic acid, and oxigen gas, are of a nature to be abſorbed

by

by the earth: ſo that here we find one of thoſe continual circulations, which, huſbanding the primary materials neceſſary for complicated compoſitions, diſplay that wiſe and rich economy of nature, which excites our admiration in ſo many inſtances while we ſtudy her phenomena.

G. *Direction.*

27. Though the phenomenon, which with many modern naturaliſts I here call *direction*, be rather one of the reſults of a function than a real function itſelf, and its ſource or cauſe is yet ſo little known, though it is extremely important to eſtabliſh its exiſtence and effects, yet we ought to treat it as if it conſtituted a function altogether, more particularly as we know not to what general function to refer it. By direction I mean that property, or living power, by which each part of the vegetable, conformably to a particular law, follows a courſe, or directs itſelf, to the nature, reſpective ſituation, or wants, of each of theſe parts. Thus it has been obſerved, that the radicle, after iſſuing from the germinated ſeed, always directs its courſe to the earth, and the plumule to the air; that the branches ſpread and riſe to enjoy the contact of air and light; that the leaves place themſelves ſo as to occupy all a particular place in the atmoſphere, ſo that their ſhining ſurface

ſurface is uppermoſt, and their rougher ſurface downward; that flowers turn toward the light and the ſun; that the young branches or twigs bend toward the water, &c.

28. This direction is ſo conſtant, and ſo neceſſary to vegetables, that the parts exhibiting it ſurmount all the obſtacles oppoſed to them, as the experiments of Duhamel, Bonnet, and Citizen Sennebier, have proved. Seeds placed in appearance moſt unfavourably, ſo that the radicle muſt come out at the top, and the plumes at bottom, ſhow themſelves at the end of a few days, the former bending down to reach the earth, the latter riſing up to get into the air. Plants bent at firſt toward the light, and afterward turned the contrary way, will ſoon change their direction: branches bent toward the earth by means of weights or cords, will ſtraighten themſelves, and riſe upward again. Leaves turned, and kept inverted on their footſtalks, reſume of themſelves their primitive poſition; and the reſtraint impoſed by art on all theſe parts is ſoon deſtroyed by the natural power, which tends to direct each to its reſpective poſition, which is peculiar to it.

29. Many hypotheſes to aſſign a cauſe for this movement have been invented and publiſhed. To explain it, ſome phyſiologiſts have admitted a kind of ſenſibility in the organs of plants, though the irritability already mentioned is the moſt that can be aſcribed to them. But it is neceſſary likewiſe to admit a cauſe, a ſtimulant producing

producing this effect: and this has been sought in the action of water, air, light, heat, the sun, and a certain relation between these and each of the parts of a vegetable. Unquestionably these substances have a direct influence, which cannot be controverted, on the direction taken by the different parts of plants; since we see this direction follows the contact or presence of each of these external substances. But how do they act to produce this effect? On what organ do they make an impression? What changes do they produce in it, and how are the changes effected from which this or that direction arises?

30 We do not find a sufficient cause for these effects either in the imbibition of water and the dilatation which ensues from it, or in the desiccation and evaporation effected more powerfully on one point than on another, or in a supposed attraction between such an organ and such a substance toward which it bends or turns itself. But on considering that all direction whatever of the parts of a vegetable is the consequence of a motion, that this always supposes the shortening of some fibres at the same time as those opposite to them are dilated, we shall perceive, that there is a stimulant action, which singularly approaches to what is observed in the irritability of animals; but that it differs in this, that its effect is permanent, and leaves the vegetable part in a constant state of contraction, which becomes a sort of habit, and the constant position of each of these parts. We can yet find

find nothing that has more probability than this explanation.

H. *Sleep.*

31. There are two kinds of ſleep in plants: one, in certain reſpects ſimilar to that of animals, takes place during the night, and returns periodically every twenty-four hours: the other longer, permanent, takes place during a whole ſeaſon, that of winter, and is termed *hibernation.* It is ſuppoſed, that during the night all plants experience ſome change, that they are not in the ſame ſtate as during the day, and we may judge of this from ſome in which the leaves are folded one upon another, often approached or brought cloſe to the ſtalk, and the flowers cloſed. It is commonly ſuppoſed, that the abſence of light, of the return of which theſe plants appear to be ſenſible by the diſplay of their leaves and expanſion of their flowers, is the cauſe of this kind of contraction; and that its preſence produces the evaporation of a fluid, to which we muſt aſcribe a kind of exhauſted ſtate, whence ſleep ariſes.

32. We may doubt the truth of the ſame effect being produced in all plants, or that they experience a ſleep ſimilar to what is obſerved in the ſenſitive plant; but it appears certain that in all the functions which they exerciſe during the day undergo modifications and differences during the night, which conſtitute

ſtitute in them that ſtate which is conſidered as ſleep. Thus the tranſpiration and iſſue of water and gas through the leaves are ſtopped during the night; the ſuction by the roots is greatly diminiſhed or totally ſuppreſſed; and plants, ſo far from loſing weight, increaſe it a little, either by imbibing water precipitated from the air, or by the abſorption which is partly continued by the roots. The privation of the contact of light, which has ſo much influence in tranſpiration, is the only cauſe of this change of ſtate.

33. As to the ſeaſon of winter, and the ſleep which vegetables experience during this ſeaſon, it is to be obſerved in the firſt place, that it occurs only in plants that live more than a year, and the duration of which varies from two to ſome hundreds of years. During this repoſe, the tree being deprived of its leaves, and reduced to its ſtalks and the buds which garniſh them, exhibits the image of apparent death; though, if compared with dead wood, there are very perceptible differences even in its aſpect. No ſap exiſts in the trunk or branches; it no longer tranſpires; it reſiſts the ſeverity of froſt, however, to a certain point, and while water freezes around it, the portion it contains remains fluid, in conſequence of its internal temperature, and of the portion of life it retains. No ſenſible change takes place in the ſleeping vegetable: the ſole effect of its life is confined at this time to the ſupport and very ſlow en-

largement

largement of the leaf-buds and flower-buds, which cover all the points from which either are to iſſue. The form, poſition, and ſtructure of theſe buds may ſtill afford the botaniſt means or characters for diſtinguiſhing it, excluſive of the appearance of the trunk or branches. The root alone retains greater activity; it is more ſucculent, and larger than the reſt of the plant.

34. All the effects of the winter-ſleep are manifeſtly produced by the lowering of the temperature. The external cold allows the fibres and the ſides of the veſſels of plants to contract or cloſe together. The organs of tranſpiration no longer exiſt: the evacuation of vapour no longer taking place, the aſcent of the ſap itſelf is interrupted. The ſolid part, or ſupports of the vegetable, remain in a ſtate of reſt, inertneſs, and ſtationary inactivity, whence ariſe the abſence of every notable chemical change in its continuity, and conſequently a ceſſation of growth. A very ſlight change takes place in the buds alone, to which the ſmall quantity of thick fluid remaining in the veſſels flows, and in which it becomes concentrated, ſo as gradually to enlarge theſe germs, and ſlowly to bring on their development, and ſhooting forth at the firſt increaſe of the heat of the atmoſphere. Events paſs ſomewhat differently in evergreens, which keep their leaves during winter, and retain in the reſinous juices, with which they are humectated, while their

transpi-

tranſpiration alſo is ſlight at all ſeaſons, ſufficient caloric to defend them from the ſeverity of the cold, and to keep up a remnant of life and motion, which, however, is much leſs than it is in hot weather. Still this difference in the ſleep of evergreens, which do not loſe their leaves, or rather this kind of natural ſleepleſsneſs, requires to be ſtudied, and may prove a ſource of new diſcoveries.

I. *Germination.*

35. The germination of ſeeds, or the phenomenon by which the germ contained in a ſeed unfolds itſelf, and becomes a real plant, of which the root penetrates into the earth, and the ſtem riſes into the air, is one of the moſt admirable and aſtoniſhing phenomena which the natural hiſtory of vegetables diſplays. It is an aſtoniſhing ſpectacle to the philoſopher, as well as to the man of the leaſt enlightened mind, particularly when the feeble exiſtence of the ſeed is compared with the tree to which it gives riſe. Accordingly, in almoſt all ages, this phenomenon has engaged the attention of the greateſt natural philoſophers, and their ſucceſſive labours have at length lifted up the veil, which nature had thrown over one of her moſt myſterious operations. Malpighi and Grew were the firſt who deſcribed with care the ſtructure of ſeeds, and obſerved the circumſtances of their germination. The firſt picture which Malpighi traced

traced of it on the feed of a curcubitaceous plant is one of the moft beautiful performances of vegetable phyfics. Grew has fhown the relation of the cotyledons to the radicle, and the continuity of this with the plumes. Homberg faw in 1693, that germination does not take place in vacuo. Ray, Ledermuller, Adanfon, Bonnet, Bierkauder, Ludwig, Krafft, Bohmer, have obferved the greater part of its moft remarkable phenomena. Achard, Ingenhoufz, and Sennebier have ftudied its caufes fubfequently to the modern difcoveries in chemiftry, and have connected them with the data of this fcience.

36. The vegetable feed, confifting of one or two cotyledons, of the radicle which has a communication with them by means of veffels, and of the plume which is continuous with the radicle; covered with two coats, the exterior folid and hard, often horny, fometimes woody, the interior thinner, doubling in, and enveloping the embryo completely formed and arrived at maturity, enjoys the property of germinating, and fometimes retains it a long time. Every feed has its time and period of germinating, from a fingle day, as certain grapes, to fome years as the hazel nut. This function however, may be accelerated by various means, particularly by the action of oxigenated muriatic acid, as Mr. Humboldt has proved, who has propofed this fimple mean of raifing in hot-houfes in botanic gardens fuch feeds, as we have not yet been able

able to make germinate. Every one knows that feeds germinate in the earth: there are fome, however, which germinate in water, or in moift air. They are made to grow alfo on fponges, tow, mofs, &c. All the organs of the feed, and their perfect integrity, are required for germination to fucceed: the removal of the cotyledons renders it impoffible.

37. The depth at which feeds are buried in the earth, requires to be in fome degree circumfcribed, for their germination to be fuccefsful. Placed too deep, the feeds do not germinate: at the furface, and when the cicatricula is not covered with earth, germination equally fails. A knowledge of all the conditions neceffary to germination will explain the neceffity of this difpofition, which is fully confirmed by experience.

Air muft be in contact with the feed for germination to take place: and when the feeds are buried too deep, the air cannot penetrate the foil, which ought befides to be well broken, to give paffage to this fluid. The prefence of oxigen gas is indifpenfably neceffary: feeds do not grow in azote gas, or hidrogen gas; but if a certain proportion of oxigen gas be added to either of thefe, the feeds will come up. Water is no lefs neceffary to germination: that which is impregnated with air promotes it much more than boiled water; and the addition of a little oxigenated muriatic acid accelerates it. We have no direct proof of the influence of electricity

city on this function, though it has been admitted by some natural philosophers.

38. An increase of temperature greater or smaller, or a more or less considerable quantity of free caloric, is one of the most essential conditions of germination. Germination has never been known to take place below the freezing point, or at 0, of the thermometer: it does not begin, at least for plants of which the seeds are known (for of the germs of the cryptogamia class we know nothing) but at 6° or 8° of the thermometer. But the requisite degree of temperature varies singularly in the different species of seeds. In general a temperature exceeding 20° of Reaumur's thermometer promotes and accelerates the germination of seeds, which will germinate at a lower temperature: the contact of light retards, or completly prevents germination, which constantly takes place in darkness. Thus a seed well formed, thoroughly ripe, entire in its organization, committed to moist earth by which it is entirely covered, buried to a slight depth, sufficient to deprive it of light and allow a passage to the air, moistened with a due quantity of water, exposed to a higher or lower temperature according to its peculiar nature, undergoes the process of germination, and in a determinate time gives birth to a plant similar to that by which it was formed.

39. When all the conditions that have been mentioned are combined, the seed begins, sometimes in a few hours, to have its coats moistened

by

by the water, which penetrates them, and likewiſe its cotyledons, which ſwell and ſoften: the circatricula enlarges and opens, the coats burſt, the radicle comes forth, and exhibits a little prominent knob, which ſoon lengthens: the ſubſtance of the cotyledons is then filled with a milky magma or pulp, of a bland ſaccharine taſte. Preſently the plume comes out, and exhibits the curved back of its ſtalk through the cleft membranes: it unfolds itſelf, and riſes towards the ſurface of the earth: the radicle grows larger on its part, its knobs extend, and become covered with little filaments. Both theſe parts conſtantly follow theſe directions, and bend in various ways to take them, whatever be the poſition of the ſeed. The plume, ſtrengthened though yet white and truly etiolated, pierces the ſurface of the earth at the end of a longer or ſhorter time, puſhing before it the cotyledons to which it ſtill adheres, and which, when once immerſed in the air, ſeparate from each other, diſplay themſelves in ſeminal leaves, and ſuffer the young plant, the point of which begins to change from white to green, to be ſeen between their parenchyma, which is withered and diminiſhed in thickneſs: preſently the cotyledons dry and fall off, when they are no longer neceſſary for its nutrition. In the monocotyledons the ſeed comes up and is carried laterally by the leaf rolled up conically or lengthened into a tongue, which ſhoots into the air.

 40. Theſe

40. Thefe phenomena announce, that the water, which has paffed through the coats, has fwollen the lobes or cotyledons, has foftened and difuted the parenchyma, and has formed of it a kind of milk, which, being carried into the radicle by the veffels of communication between thefe two parts, has extended, developed, and elongated it, fo that it is continued out of the feed. This radicle, once fwelled and diftended in its internal texture by the milk of the nourifhing lobes, tranfmits to the plume, the channels of which are dilated by the heat, the milky nutriment it has received: and the plume, injected as it were with this alimentary fluid, unfolds itfelf; all its veffels, filled with juice, fwell, and exhibit ribs or prominent lines on the leaves. This effect of nutrition, very rapid at the commencement of vegetable life, quickly raifes and elongates the plume, which becomes a plant. Thus the radicle fupplies it with the vegetable milk which it draws from the lobes, till its filaments grow larger, and form a number of mouths of fufficient fize and activity to draw from the earth the juices it offers. Then the young plant, hitherto fupported by the proper fubftance of the cotyledons, beginning, when it has rifen into the air, to receive the influence of light and the heat of the atmofphere, tranfpires copioufly, and thus obliges the radicle to fupply it from the earth with the fluid, which it requires for its growth. At this period the exhaufted co-

tyledons become uselefs, and fall off: the plant lives by its own powers.

41. All thefe effects are accompanied by chemical charges which produce them: the farinaceous feculent matter of the lobes or cotyledons, which is at the fame time more or lefs oleaginous, being diluted by the water which the coats impart to it, forms a peculiar emulfion, which undergoes a real fermentation by means of heat: a faccharine matter is formed in it, the prefence of which is attefted by its decided tafte in germinated feeds, particularly in thofe that are termed corn: this matter contributes to the nourifhment of the young plant: it is foon converted into fap, and into the proper vegetable fubftance: its fermentation is accompanied with the formation of a certain quantity of carbonic acid, which is decompofed in the young plant the moment it is ftruck by the light, and yields to it its carbon the firft principle of its commencing folidity. Thus, germination is effected by a chemical action or power, eafily difcovered and determined by phenomena fully obferved; and the organization does not act its part, nor is the principle of life eftablifhed in the vegetable, till after the abforption of water and caloric, the emulfive folution of the cotyledons, the formation of a muco-faccharine matter, and that of carbonic acid, the firft impreffion of which on the vegetative power of the plant begins with developing in it that irrita-

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bility which grows with it. This ſimple and natural explanation of germination undoubtedly announces, that one firſt ſtep has been made in vegetable phyſics by means of the light which chemiſtry affords; but many others remain, that may be expected from the further progreſs of this ſcience.

K. *Foliation.*

42. Foliation, or *coming into leaf* as it is called, is the phenomenon by which leaves unfold themſelves, and ſpread in the air, either at a certain period of vegetation in annual plants, or at a particular period of each year in the perennials. This eruption of the leaves is one of the grand functions of plants, ſince theſe organs act a very important part in vegetable life, as has been ſeen. It is in ſome reſpect a ſecond germination: it is the formation of a part, which completes the organization neceſſary to the ſupport of theſe beings. The reſult of it is a multiplication, an extenſion of ſurfaces, which eſtabliſh a communication between plants and the air, the important conſequences of which are vigorous vegetation, and all the functions that accompany it. The leaves exiſt at firſt, completely formed, but very ſmall, and cloſely folded together, in buds of a particular ſhape and

and ftructure: at a certain temperature, which muft be at leaft of 10°. for moft plants, and aided by the contact of light, the buds open by the feparation of the fhells in which they were enclofed, and the leaves fpread themfelves in the air.

43. The opening of the buds and feparation of the fhells are manifeftly owing to the motion of the fap, which fwell and diftend their veffels, as well as thofe of the leaves. Thefe buds, during their hibernation or winter's fleep, at firft grow very flowly. The leaves injected by the fap impelled forward or imbibed at firft ftep by ftep, acquiring a greater increafe in the fpring, pufh out and feparate the fhells, which kept them diftinct and bound up: prefently they lengthen their foot-ftalks, and fhoot with rapidity into the air, with which they keep up an extenfive contact. From this time the ftate of the plant is fingularly changed. The expanded leaf at firft affumes a pale green hue; ftill retaining a yellowifh tinge, it is filled with a mucous, glutinous juice of little tafte: when rubbed between the fingers it invifcates them, and makes them ftick together. This mucilaginous nature continues but a few days: the leaf, as it unfolds itfelf more, lofes this glutinous fluid. In proportion as its colour heightens, its parenchyma and lefs abundant moifture become bitter, acrid, afcerb, combuftible, extractive, or aromatic, affuming in fhort a different chemical character.

44. These successive changes, which take place in the leaves at the same time as the vegetable, grows, transpires, and decomposes the water and carbonic acid in its organs, are irrefragable proofs that a chemical effect, a series of decompositions and various combinations, take place in their vessels, and particularly in their cells, which occasions the difference of taste, smell, consistence, and colour, observed in their texture, from the commencement of foliation till the functions of the leaves terminate. It is even probable, that of all the organs of vegetables the leaves are those, in which chemical attractions, and the changes that arise from them, take place with most energy; since these organs with their numerous and very distinct vessels, exhibit in the net-work they form a pulpy, medulary, or cellular texture, very suitable to these effects, in consequence of the room they afford, the fluids with which this texture is moistened, and and the stay they allow them to make.

45. Leaves offer to the observer another period, not less remarkable than that of their eruption, when they have fulfilled the functions which Nature has assigned them. Their colour, from a green more or less deep, gradually grows pale and disappears, turning to a yellow or fawn colour, either all over at once, or in parts. They lose their substance, and become thin: their freshness and verdure disappear: they grow darker coloured, and wither. Soon after these changes

changes their ſupport contracts, ſhortens, and dries, quits the part of the branch to which it adhered, and falling carries with it the leaf, already ſome time dead. It is ſcarcely neceſſary to remark, that this phenomenon of defoliation is accompanied by chemical changes, to which it even appears to be owing: the fluids have grown thick, and none reach the leaves at a certain period of their decay: tranſpiration then ſtops; and we ſee that the fall of the leaves is the ſignal of the ſlumber, that commences in the plant.

L. *Flowering.*

46. Flowering, or the formation and expanſion of the flowers, is one of the moſt important periods or events in vegetable life. As it is its principal purpoſe, it coſts many efforts; it exhauſts in ſome ſort the plants in which it takes place. All the work of vegetation that precedes it being deſtined to produce this flowering, when it has taken place, the plant is much weakened, and the remains of ſtrength it preſerves ſuffice only for fructification. To underſtand the connections of this function with chemical phenomena, I need only exhibit its moſt general reſults.

47. The flower, long prepared and organized in its bud, which is more round and diſtended than

than that of the leaf, opens at a given temperature, which differs in different plants. As they follow an order of days in their fucceffive expanfion, the flowers of a diftrict furnifh botanifts with a calendar of Flora. After it has opened, the petals of the corolla become coloured; the influence of the air and light is of great importance in producing this colour: an excretion of faccharine matter takes place in a particular point of the corolla, which is called the *nectary:* odoriferous effluvia frequently emanate from the petals, which conftitute a perfume more or lefs prized. The ftamens, or male organs, commonly approach the piftil or female organ, and fhed their fecundating duft on the ftigma. A matter, probably of a vaporous nature, traverfes the ftyle, and proceeds to ftrike or impregnate with vitality the feeds placed in the ovary. This function once fulfilled, the anthers dry, the filaments of the ftamens wither, the petals wrinkle and drop off, and the fructification commences.

48. In this fucceffion of remarkable phenomena, which conftitute flowering, we cannot overlook a feries of chemical operations. Each part of the flower is continuous with a correfpondent organ, from the calyx which is propagated from the bark, to the piftil which confounds itfelf with the extremity of the medullary texture. The juices are prepared before they arrive at thefe parts; but they unqueftionably undergo

undergo ſome modification, a ſecond and definitive elaboration, in the organs of the flowers. The fecundating duſt of the anthers, termed *pollen* by botaniſts, the aromatic honey of the nectaries, the odoriferous vapour of the petals, are ſo many products of this chemical elaboration. The colouring of the corolla by the air is equally a conſequence of chemical alterations, which the flowers experience in their texture. We know nothing yet of the cauſe of fecundation: it is not impoſſible that it may be concealed in ſome effect of chemical affinity, which has hitherto eſcaped the reſearches of naturaliſts.

M. *Fructification.*

49. WHEN fecundation has taken place, and the organs that have effected it, as well as thoſe which ſurrounded and protected them, have diſappeared or fallen off as mutilated, the fertile ſeeds gradually enlarge in the ovary, the fruit is formed, and acquires a more or leſs conſiderable growth. This furniſhes itſelf with pulp, fleſh, mucilage, parenchyma, huſk, membranes, ſhell, kernel, and all the moſt varied kinds of envelopes, intended to cover and preſerve the ſeed to perfect maturity. Moſt of theſe acceſſaries ſerve at the ſame time to nouriſh the ſeeds, to ſupply them with aliment ſuitable to their nature, or to afford

afford the veffels which convey it a fupport, and perhaps impart a peculiar nature to them. This flefh or pulp of fruits is fweet, faccharine, acid, flat and mucous, bitter and acrid, oily, afcerb, and in general of very various taftes and chemical properties.

50. Who does not fee, in this work of fructification, the refult of a chemical power and action, as well as in the growth and nutrition of the different parts, particularly of the lobes or cotyledons of the feed? A conftant identity of effects gives birth in the internal part of the fruit, or in the feed, to the formation of fecula, fixed oil, and gluten, fince all feeds uniformly exhibit one or other of thefe principles: but a great variety of chemical compofitions or productions prevails in the pulp or parenchyma of fruits. The regularity of the former refult, and the variety of the latter, certainly depend on the ftructure and different organization of thefe two kinds of parts. Befides, external circumftances, the rays of the fun, the temperature, the drynefs or moifture of the air, the winds, water, influence the nature of the parenchyma of fruits, which are always expofed to them; while the more important fate of feeds, of which fruits are but the defending coats, is entrufted to an interior organization, a central, choice, and regular ftructure, always the fame, never variable, and which cannot be modified by external accidents.

Article X.

Of the Modifications which Art produces in Vegetables, of the principal Changes of which they are ſuſceptible, and of the Diſeaſes by which they are affected.

1. FROM the particulars contained in the preceding article it appears, that vegetables are real machines, in which many chemical operations take place, conſiſting generally in triple combinations at leaſt of the primitive principles furniſhed by the earth. Accordingly, they are liable to be greatly affected by all external ſubſtances. It is from the influence of theſe, directed according to the will of the cultivator, that plants experience modifications and changes, the production of which augments the enjoyments of man: long experience has certified and multiplied theſe modifications, ſo that they are become the object of an art of great importance in ſociety, which includes agriculture among its various practices.

2. The purpoſe of cultivation is to multiply vegetables, the properties of which fit them for the food of man, his clothing, the conſtruction of his habitations, the mitigation of his diſeaſes, and the gratification of his ſenſes, particularly thoſe

thofe of fight, tafte, and fmell. Vegetables are multiplied either by fowing or planting fuch as nature offers fingly, rare, or in little abundance. Cultivation propofes not folely to increafe the quantity of thefe ufeful beings in the proportion our wants require, but to make them grow in the fhorteft time poffible, fheltered from the dangers to which they are liable, and in the greateft poffible quantity on a given fpace. It attains this object by choofing the foil fuitable to each particular feed and plant, preparing it by the fpade or the plough, enriching it by burying in it vegetable or animal matters, removing the injurious plants which grow in it fpontaneoufly, and giving, either to the foil or to the plant committed to it, from the moment of fowing or planting to that of gathering the produce, all the treatment capable of favouring the growth and multiplication of the vegetable. It varies its means, according to the nature of the foil, and of the plants cultivated in it, conformably to the order of the feafons, and the temperature and afpect of the place.

3. The object of agriculture, confidered in the great, is likewife to furnifh a fufficient abundance of food for animals ufeful to man; to enable them to repay the earth what they take from it by confuming its produce; and the fcience and great fuccefs of this firft of arts truly confift in the exact proportion of animal

to

to vegetable productions. It is carried toward perfection when these two kinds of productions are so well regulated and arranged in their mutual relations to each other, that nothing is wanting to these animals, and that they furnish a proportion of manure more than sufficient to continue that fertilization, of which they afford a constant source in their excrements and litter. Thus by incessantly renovating the fertility of the earth, this in return ought to give them what is necessary to furnish man with wholesome food, materials for clothing him, and assistance to convey his burdens, to till the ground, and for all the purposes to which animals are applied in a domestic state.

4. The numerous experiments which have been made in a long series of ages on the culture or multiplication of vegetables by art, have led to a number of results, not less interesting in the natural history of vegetables, than useful to the wants and tastes of civilized man. These have taught us to multiply trees and plants by grafts and layers; to enlarge their stems; to spread, blanch, or colour their leaves; to alter their fruits in size and flavour; to double their flowers; to cross their breeds, and produce mule plants; and to establish varieties, which nature had not given to man, and which, being perpetuated by cultivation, have received and merit in agriculture the name of *species*. The arts of manuring land, of grafting, pruning, and

laying down trees, of ſheltering them and ſupporting them in eſpaliers and againſt walls, of giving them ſuch a form in height or ſpread as ſuits the place where they are planted, of accelerating or retarding their maturity, of varying the taſte, ſize, and ſhape of their fruits; that of producing in a temperate or cold climate in hot-houſes, in hot-beds, under frames, under bell-glaſſes, in hot and factitious earths, plants which nature placed only between the tropics, or under the equator; that of varying the colours and perfume of flowers, of doubling them, or converting their ſtamens into numerous coloured petals: all theſe wonders of cultivation, which vary and multiply our enjoyments, are capable of being explained or underſtood by means of the chemical notions that have been developed in the preceding articles.

5. In fact, it is by increaſing nouriſhment, by the addition of abundant manure; haſtening vegetation by an artificial and increaſed temperature; opening the boſom of the earth by frequent and deep ſtirring to the beneficial influence of the light and air; conveying to it by irrigation, trenches, or the watering pot, an abundance of water, which the atmoſphere withholds too long, or furniſhes in too ſmall quantity; fecundating one ſpecies of flower with the pollen of another nearly allied to it; impregnating water with a very nutritious vegetable juice, very ſuſceptible of fermentation and

and heat; ſtopping the motion and courſe of the ſap in ſome parts of the plant by bending it, tying it, or cutting the bark; forcing a portion of one tree, or bud-bearing bark, to inſert itſelf into another, and live at the expenſe of its juices, after having agglutinated or made it unite into one ſubſtance with it by grafting; conducting all the nutriment to the fruit-buds, by removing ſome branches which would conſume too much ſap; adding to the earth ſtimulants, which, being conveyed into plants with the water that their roots imbibe, give activity to their vegetation: in ſhort, by employing a great number of proceſſes and agents truly chemical, the cultivator, frequently even without having any conception of the cauſe or mode of action, but always guided by practice of more or leſs continuance and ſucceſs, produces all the changes and modifications that anſwer his wiſhes.

6. But all theſe firſt data, all the applications of chemical ſcience to the phenomena of the artificial cultivation of vegetables, are yet only the firſt glimpſes or perceptions, the exiſtence and importance of which have been conceived or even ſuſpected by the moderns alone. Wallerius had already laid ſome of the foundations of agricultural chemiſtry; Bergman had carried them a little farther in turning his attention to earths; and Lavoiſier has ſince diſplayed all its importance. Theſe firſt ideas have yet

ſcarcely

ſcarcely excited the attention of a few of the inhabitants of the country: when will enlightened citizens, weary of the tumult and factitious pleaſures of cities, carry into the country the knowledge with which their minds are ſtored, and apply to agriculture the rich reſources of phyſical ſcience!

7. The deſtiny of plants, conſidered as chemical implements employed by nature to form the firſt triple or quadruple compounds, to unite by complex attractions at leaſt three primitive ſimple ſubſtances, and often more, muſt be to change perpetually their ſtate, to remain but a little while in the ſame order of compoſitions, and to experience, from the very nature of the multiplied powers which re-act on their principles, variations that more or leſs profoundly alter their materials. If the external circumſtances, if the exterior agents, which influence, as has been ſhown, their intimate nature, come to experience ſudden and great alterations; if the air change quickly from temperate to cold, from dry to moiſt; if it ſtrike plants too rudely; if particularly it be too long loaded with water; if froſt unexpectedly ſucceed mild weather after the firſt efforts of vegetation in ſpring; if a violent wind carry off too abundantly from the leaves, as well as from the earth, the water which circulates in the former and humectates the latter; if after rain, a burning ſun dart on vegetables covered with water,

water, each drop of which concentrates its rays like a lens; if the deluged ground do not allow too large a body of water to flow off, all theſe cauſes, and a great number of others, become ſo many ſources of alterations more or leſs injurious to plants, and diſeaſes are produced in them, as well as in animals.

8. It even ſeems, that, modified by our cares, rendered more ſenſible and delicate by culture, participating in ſome degree the inconveniences of that ſort of domeſtic life or civilization to which we have brought them, plants, like ourſelves, and like domeſtic animals, are more expoſed to indiſpoſitions and diſeaſes than thoſe which grow ſpontaneouſly in the places man has ſtill left to nature. It is rare that the ſame number, and particularly the ſame kinds of diſeaſes, attack the trees of the foreſt, as thoſe which very frequently we ſee only in our orchards. The plants of our fields, eſpecially our corn, are affected with diſeaſes, which we ſcarcely ever, if at all, obſerve in thoſe that grow wild. It may be ſaid, that their multiplication, and their being crowded together in one ſpot, and in too confined a ſpace, ſometimes occaſion them the ſame injury, as men and animals experience from the incumbrances and throng of too cloſe a place. It is true, on the other hand, that the care of the cultivator protects them from the teeth and ſtings of animals and inſects, to which nature expoſes

 the

the vegetables ſhe produces, and for which ſhe even appears to have deſigned them. But the greatneſs and danger of the diſeaſes, in ſome ſort to be conſidered as ſocial, and frequently endemial or even epidemic, which attack the vegetable tribes cultivated in our fields, do not allow us to imagine that there is, in this reſpect, a compenſation favourable to the cultivator.

9. Without giving here an enumeration, which would be out of place, I ſhall content myſelf with obſerving, that, notwithſtanding the little care that has been taken to diſtinguiſh and deſcribe all the diſeaſes of plants, we know enough to perceive, that no vegetable, and no part of a vegetable, is exempt from them. The trees of orchards, gardens, parks, avenues, and highways, frequently ſhow their bark cleft and cracked, corroded by dry or moiſt ulcerations, enlarged by tumours, pierced and diſſected by inſects, torn by beaſts, exhauſted by paraſitical moſſes and lichens. Their wood bends, ſplits, dries, ſwells: we ſee it attacked by *mouldineſs*, *ulcers*, *excreſcences*, *knobs*, and *wounds*. The leaves of plants are liable to *mildew*, *blaſt*, *blight*, *parching galls*, *premature decay*, *loſs of colour*, *curl*. The enemies and ravagers of our harveſts, and the graſs tribes, are the *ſhedding of the grain*, *caries*, *horn*, *and ſmut*. In all theſe caſes, already obſerved with ſome care, we ſee the organs of vegetables change

change their figure, confiftency, colour, tafte, and fmell, and confequently their chemical nature.

10. Who will deny that all thefe difeafes are accompanied by chemical changes and accidents, which we ought to confider not only as their effect, but often as their caufe? Has it not been found, that in fmutty, carious, and horned rye or wheat, there no longer exifts any amylaceous or glutinous fubftance, but here an oily fluid, there an acrid and coaly extract? Are not wood and bark, when ulcerated and covered with a blackifh fanies, or whitifh, gritty, and dried cruft, loaded with acetite of lime and of pot-afh, tannin, refin, and carbonate of lime and of pot-afh, according to the experiments of Citizen Vauquelin? Who can limit the capacity of chemiftry for acquiring a knowledge of the nature, caufe, and remedies of thefe difeafes? Let us hope, that, with all the lights which this fcience affords to agriculture, this investigation will no longer be neglected: let us truft, that this pleafing tafk, begun under fuch happy aufpices, will no longer be delayed; and let us depend on thofe ardent, ftudious youths, who will carry with them into the country ufeful knowledge, and who will not allow the firft of arts to remain chained down to blind cuftom, to prejudices deftructive of every thing that is good. In fine, let us be perfuaded, that the period, when the labours of the

END OF THE EIGHTH VOLUME.